

Volume III

Final Supplemental Plan for Combined Sewer Overflow Control

Plan For Secondary
Treatment Facilities
and Combined
Sewer Overflow Control

An Amendment to Metro's Comprehensive Water Pollution Abatement Plan

*****METRO

Clean Water A Sound Investment

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Prepared by Culp, Wesner, Culp Consulting Engineers and Ott Water Engineers

for Municipality of Metropolitan Seattle

SUPPLEMENT TO FINAL PLAN FOR COMBINED SEWER OVERFLOW CONTROL

MUNICIPALITY OF METROPOLITAN SEATTLE

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SUMMARY

PURPOSE

Metro is proposing to amend its Comprehensive Water Pollution Abatement Plan for the Seattle-King County metropolitan area by adopting a facilities plan that will: (1) upgrade Metro's system to secondary treatment and (2) further control combined sewer overflows. Metro would implement the plan in phases, constructing facilities to serve immediate needs and constructing additional facilities as needed through 2030.

This supplemental CSO plan compares the combined sewer overflow (CSO) control aspects of five secondary system alternatives and provides information so that a CSO control plan can be adopted. The basic purpose of this supplement is to describe and analyze the CSO control aspects of an additional system plan proposed for study by the City of Seattle and to compare these CSO control aspects with those of the four secondary system alternatives previously studied in detail, as described in Volume III of the November 1985 plan.

METHODOLOGY

The proposed CSO control plan has four basic elements: (1) a target goal for reducing CSOs throughout the Metro system; (2) a set of criteria for evaluating which CSOs to control and in what order of priority; (3) a planning process for analyzing specific proposed CSO projects; and (4) an initial group of CSO control projects proposed for implementation by 1995.

The evaluation criteria and planning process are described in this document. The actual target goal and initial group of projects will be decided by the Metro Council in July 1986, after considering the analysis in this volume, the environmental impact statement (EIS), and related documents, in connection with adopting a secondary treatment facilities plan. Chapter 1 of this volume explains the nature of the CSO control plan and planning process.

As explained in Chapter 1, the target reduction goal is based on a type of cost-benefit analysis in which CSO control efforts are carried out until the costs rise disproportionately to the CSO reduction that can be achieved. The point at which the cost curve rises is called the "knee of the curve."

In order to estimate the costs of CSO control, representative CSO control projects have been analyzed. The purposes of developing representative projects include: (1) to see if a particular CSO is technically capable of being controlled; (2) to estimate the cost of controlling a CSO; (3) to gain an appreciation at a plan level for the types of environmental impacts that could be involved; and (4) to use them as the "building blocks" of a planning process (explained further below).

Representative projects are based primarily on a cost-effectiveness criterion, in other words, the least expensive control technology for the greatest volume of CSO reduction. For example, unless separation is more expensive than other technologies for controlling a particular CSO, separation would be used (separating the sewage and sending it to the treatment plant, and returning the stormwater to the local drainage system). In certain locations, there may be reasons for using a different method of control, and the proposed evaluation criteria allow for making case-by-case judgments.

Each of the seven secondary system alternatives under consideration by the Metro Council would reduce CSOs by a certain amount, as a result of the facilities (treatment plants, conveyance lines, and so on) that would have to be built to implement secondary treatment. In order to make each system alternative equal for CSO control, it is necessary to determine what additional CSO control projects could be implemented.

These additional CSO projects are the building blocks referred to earlier. Each representative project, with its estimated cost, can be added to the next to achieve a desired level of CSO control. The CSO plan and EIS documents therefore consider a very wide range of alternatives.

The City of Seattle proposed that goals of 75 and 90 percent CSO volume reduction be specifically analyzed in the supplemental plan and EIS. The November 1985 CSO control plan did not select CSO project combinations to achieve specific volume reduction goals, but instead combined projects only until the knee of the curve was reached. This supplement therefore analyzes, among other things, the representative projects that could be added to each of the seven system alternatives to achieve the 75 and 90 percent goals.

Although most of this document and the accompanying documents focus on analysis of possible control projects for specific CSOs, it is important to remember that these are representative projects for planning purposes only. The Metro Council has not yet decided to propose or implement any particular project. Each CSO that is proposed to be controlled will receive its own appropriate environmental review, including alternative projects for controlling the identified CSO and alternative locations for the project, including non-shoreline and non-park alternatives.

PROJECTS EVALUATED DURING SUPPLEMENTAL CSO CONTROL PLANNING

In addition to the CSO control projects identified in the November 1985 plan, several additional projects were evaluated, as described below.

The large Duwamish and split Interbay/Duwamish versions of the fifth secondary system alternative potentially involve construction of a new interceptor that runs in the reverse direction of the Elliott Bay interceptor (EBI). The portions of the EBI no longer used to convey sewage could be used for storage of combined sewage during storms. Storage in the abandoned EBI (12.2 million gallons of storage in the large Duwamish configuration and 6.3 million gallons in the split Interbay/Duwamish configuration) was found to be a cost-effective CSO control option for the fifth secondary system alternative.

The potential was evaluated for increasing the size of the new regional interceptor and treatment facilities in the fifth secondary system alternative to handle more combined sewage flows. In all plant configurations (large Duwamish, large Interbay, and split Interbay/Duwamish), increasing conveyance capacity to about 457 mgd provided the least-cost combination of CSO control projects and conveyance capacities. This combination was the most economical for both 75 percent and 90 percent CSO volume reduction.

Use of large-diameter pipe storage in the vicinity of Alaskan Way was evaluated but found to be prohibitively expensive. Storage projects in the Kingdome and Diagonal Way areas were also evaluated. The Kingdome storage project was found to be 116 percent more costly than the separation project (\$41,000,000 versus \$19,000,000), and the Diagonal storage

project was 10 times more costly than separation (\$30,000,000 versus \$2,900,000). The abandoned portion of the North interceptor (NI), including the Fort Lawton tunnel, could be used for storage in the large Duwamish configuration.

Fourteen potential sewer separation projects in the Northern Service Area (NSA) were evaluated to increase the level of NSA CSO volume reduction to 90 percent. Several of these, as well as construction of other CSO control projects, would be required to achieve 90 percent NSA CSO volume reduction for all five secondary system alternatives.

Use of portions of the NI, including the Fort Lawton tunnel, as storage would be valid for the large Duwamish configuration. In the options using an Interbay plant, the Fort Lawton tunnel would be used for the Interbay plant effluent transport system and could not be used for storage.

Added NSA storage was considered. Use of the abandoned portion of the NI for storage in the large Duwamish configuration was effective for both 75 percent and 90 percent CSO volume reduction. Storage at University was required to achieve 90 percent CSO volume reduction for all secondary system alternatives.

COSTS

Costs for alternative CSO projects were first compared with a common startup date of 1991. Representative CSO projects were selected for each secondary alternative. The present-worth costs of the representative CSO control projects were calculated using phased construction of the CSO control projects over the next 20 years.

The total present-worth costs of secondary treatment and representative CSO control components of each of the five secondary system alternatives are:

1988 Present-Worth Costs (in \$1,000,000)

Secondary System Alternatives	Secondary Treatment Costs	CSO Co CSO Volum 75%	osts for me Reduction 90%	•	am Costs for ne Reduction 90%
1	1,416	104	188	1,520	1,604
2	1,232	104	188	1,336	1,420
3	1,309	157	256	1,466	1,565
4	1,116	157	256	1,273	1,372
5 - Large Duwamish	1,467	127	177	1,594	1,644
5 - Large Interbay	1,389	128	200	1,517	1,589
5 - Split Interbay/					
Duwamish	1,506	137	206	1,643	1,712

The above CSO control costs differ from those shown in Volume III of the November 1985 plan for several reasons:

- The representative CSO control project combinations used in Volume III for each secondary system alternative were selected on cost/benefit considerations and did not provide 75 percent CSO volume reduction in the Northern and Southern Service Areas.
- The present-worth costs in Volume III were based on construction of all CSO projects by 1991; the above present-worth costs are based on project-phasing assumptions compatible with the present-worth costs for the secondary systems.
- At the request of the State Department of Ecology (DOE), a treated-CSO outfall has been extended into Elliott Bay from a Duwamish CSO treatment facility, adding \$19,000,000 to the cost of the facility.
- At the request of the City, the facility that would treat CSO from Denny Way has been moved from a location under Myrtle Edwards Park to a point 1,000 feet to the east, at an added cost of \$3,200,000 for all five secondary system alternatives.
- As a result of improved data and models, the projected quantities of CSO that must be removed to achieve the target reductions have increased.

Table S-1 summarizes the representative CSO control projects for each secondary system alternative. The representative projects are those that achieve the target CSO volume reductions at the lowest cost for each secondary system alternative.

In the November 1985 CSO plan, Metro recommended a level of CSO control based on the knee of the cost-benefit curve; that is, the point at which costs begin to increase more rapidly than the corresponding benefits. With this approach, the following CSO reductions and costs would be experienced (present-worth costs based on phased construction):

Secondary System	_% CSO	Volume F	Reduction_	Present-Worth CSO Costs
Alternative	NSA	SSA	Overall	(millions, dollars)
2	50	74	69	39
4	42	65	61	51
5 - Duwamish	49	72	68	68

For the representative project combinations shown in Table S-1, the overall reduction in the CSO pollutant loadings is similar for each of the secondary system alternatives, although system alternatives 1, 2 and 5 provide slightly greater reductions. The CSO-related loadings to individual freshwaters are essentially equal for the five secondary system alternatives/representative CSO project combinations. The locations of the loadings to the saltwaters differ in that secondary system alternatives 1, 2, and 5 transfer more of the reduced CSO loadings to central Puget Sound than do alternatives 3 and 4. As a result, the CSO-related loadings to Elliott Bay are less for system alternatives 1, 2 and 5 than they are for system alternatives 3 and 4. There are no data that indicate these differences in CSO-related loadings would be of any water quality significance.

ÍABLE S-1
REPRESENTATIVE CSO CONTROL PROJECTS FOR EACH SECONDARY SYSTEM ALTERNATIVE FOR 75 AND 90 PERCENT CSO VOLUME REDUCTION

				SECOND	IRY SYSTE	SECONDARY SYSTEM ALTERNATIVES	TIVES			
CSO CONTROL PROJECT	~ I	1 & 2	MI	3 & 4	5 - 0	5 - Duwamish	2 - 2	5 - Interbay		5 - Solit
	22	8	<u>75x</u>	808	75%	80%	12X	80%	22	8
VSC									l	1
CATAD Modifications	•	•	•	•	•	•	•	•	•	•
Hanford Separation	•	•	•	•	•	•	•	•	•	•
Duwamish Secondary Plant	•	•			•	•	•	•	•	•
Diagonal Separation (1)	•	•	•	•	• •	•	,		•	•
Kingdome/Industrial Area Separation(1)	•	•	• ,•	•	, AL	•	•	•	•	•
Michigan Separation (1)	10%	77.5	9	•	400	•	• [•	•	•
Denny CSO Treatment		•		•		•	40%	•	32%	•
Increase New Regional Interceptor &		•	•	•	•	•		•		•
Primary Treatment Capacity to 457 mgd					•	•	•	•	•	•
Storage in Abandoned Portion					•					
of Elliott Bay Interceptor					•	•			•	•
Duwamish CSO Treatment				•						
				•						
NSA										
CATAD Modifications	•	•	•	•	•	•	,			
Green Lake/1.5 Sep.	•	•	•	•	•	•	•	•	•	•
Parallel Fort Lawton Tunnel	•	•	•	• •	•	•	•	•	•	•
University Storage	,	•	•	• •		,				
Separation Projects (2)	25%	62%	58%	45 %	***	• 6	• į	•	•	•
Storage in Abandoned Fort Lawton Turnel		į		\$	§ •	.	200	•	37%	Ĕ
Carkeek Stormweather Plant	•	•	•	•	•	•				
Alki Stormweather Plant	•	•	,	•	•		• •	•	•	•
CSO Equalization at Alki		•	•	•	•	•	•	•	•	•
Secondary Plant			•	•						
CSO CONTROL COST, PRESENT WORTH (3)										
(millions, 1988 \$)	70,	188	157	526	127	17	128	200	137	506
)

Percentage of basin separated to achieve target volume reduction (● = 100%).

(2) Percentage of 14 NSA separation project costs required to achieve target volume reduction.

(3) CSO projects phased as shown in Appendix C, 1987-2005; discount rate = 10%; inflation = 6% general, 7% construction, 8% energy.

Chapter 1

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CHAPTER 1

INTRODUCTION

THE COMBINED SEWER OVERFLOW PROBLEM

Substantial portions of Seattle are served by sewers that convey both sewage and stormwater. Overflows caused by excess stormwater in the combined sewers in the Seattle system have impacted water quality along the shorelines of Lakes Washington and Union, the Ship Canal, the lower Duwamish River, Elliott Bay, and Puget Sound beaches in West Seattle and Magnolia. The location, frequency and volume of combined sewer overflow (CSO) have been greatly reduced in recent years through City of Seattle projects such as sewer separation and construction of special storage tanks, and Metro projects such as pumping station upgrades and operation of a computer-control system known as CATAD that regulates flows in the sewerage system to get maximum use of storage capacities in the existing pipes. All CSO along Lake Washington and West Seattle beaches has been controlled to at least the one-year storm level.

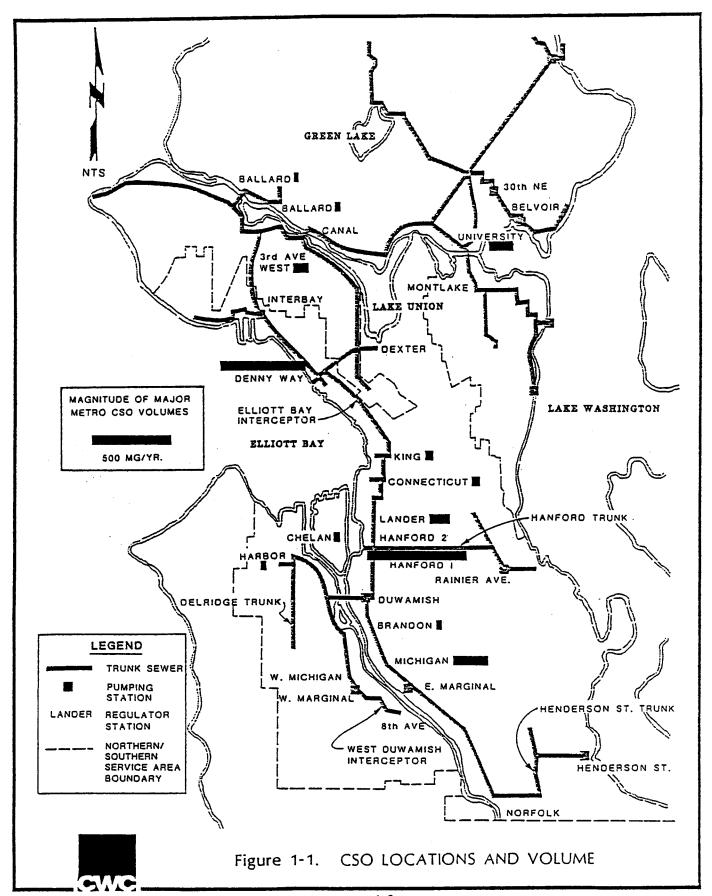
While much progress has been made, overflows persist. In an average rainfall year, over 2 billion gallons of untreated sewage mixed with stormwater still spill from 20 CSO points in Metro's West Point collection system. Additional overflows occur through City of Seattle CSO points. Of the Metro total, about 460 million gallons overflow in the Ship Canal and Lake Union, while 1,900 million gallons spill into the lower Duwamish River and Elliott Bay. Figure 1-1 summarizes the locations and volumes of the major overflows. Volume III of the November 1985 facilities plan contains detailed information on the physical characteristics of the Metro collection system and the existing CSO. As shown in Volume III, the major CSO locations identified for potential control (in decreasing order to magnitude of CSO volume) are: Hanford, Denny Way, Michigan Avenue, University Way N.E., Third Avenue West, Lander, Connecticut, Ballard, King Street, Harbor, Chelan, and Brandon. The State of Washington requires ". . . the greatest reasonable reduction of combined sewer overflow at the earliest possible date."

DESCRIPTION OF PROPOSED CSO CONTROL PLAN

Metro's proposed CSO control plan has four basic elements:

- **XX** A target reduction for CSOs.
- A set of evaluation criteria for selecting the CSOs to be controlled and the priority of CSO control projects.
- ** A planning process for making project-specific decisions in the future.
- **M** An initial group of projects to be implemented by 1995.

A target reduction goal involves the adoption by the Metro Council of a systemwide target goal (in percentage) for reducing CSOs over a period of time to be specified by the Metro Council, along with an initial group of projects to be operating by 1995 based on the analysis in the planning process and environmental evaluation.



The goal would be selected by determining the knee of the curve in the cost of the representative CSO projects for whichever secondary treatment facilities plan is adopted by the Council (see explanation in the Summary to this volume). The knee of the curve, and the corresponding numerical goal, may change as projects are implemented, because the actual projects and costs may differ from representative projects after project-level evaluation of costs, technology, and other evaluation criteria specified in Chapter 3.

PLANNING PROCESS AND EVALUATION CRITERIA

The planning process for implementing the CSO control plan establishes requirements to: (1) identify the CSOs to be controlled; (2) identify and evaluate representative projects which show that it is possible to control the identified CSOs; (3) evaluate the costs and impacts in achieving varying reductions in CSO volume, based on a cost-benefit/knee-of-the-curve analysis; (4) consider criteria for evaluation of specific CSOs to control, and their priority in the overall plan; and (5) select a plan that will establish the level of CSO control that represents the greatest reasonable reduction, taking into account both environmental and economic considerations.

In developing a list of recommended CSO control projects for the plan, a number of evaluation criteria were considered and are discussed in Chapter 3. During implementation of the plan, further evaluation of individual CSO control projects will be conducted. This will include analysis of alternative projects and project locations (including non-shoreline and non-park alternatives), additional public participation, and monitoring the CSO projects effectiveness. Advantages inherent to specific projects will be assessed in terms of their impacts on the environment, their cost-effectiveness in the overall scope of the plan, and the effect of their cost-effectiveness on the established cost-benefit curve. As the evaluation criteria are applied to a project, appropriate project-specific technology will be assessed.

In November 1985, Metro established a five-volume plan for secondary treatment and CSO control. This plan presented four alternative secondary system configurations and representative CSO control projects that could be used with each secondary configuration.

Under terms of a two-party Memorandum of Agreement, the City of Seattle and Metro agreed in January 1986 to study additional alternatives for secondary treatment and CSO control. The Memorandum of Agreement called for preparation of a supplemental environmental impact statement on a fifth secondary system alternative in which the West Point treatment facilities would be relocated to a non-shoreline site. The Memorandum of Agreement also called for added studies of CSO control alternatives associated with this fifth alternative, to supplement the information on CSO control alternatives presented in Volume III of the November plan and to refine the earlier evaluation of CSO control alternatives associated with the other four secondary system alternatives.

The November plan and related technical memoranda described the types of and environmental differences among CSO control technologies, as well as representative projects that could be used with the first four secondary system alternatives to reduce the identified CSOs. This draft supplemental plan has been prepared so that the CSO control aspects of all five secondary system alternatives can be compared.

This supplement identifies representative CSO control projects that can be used with the fifth secondary system alternative. As in the November plan, these representative projects constitute "building blocks" that can be combined in different ways to produce levels of CSO control ranging from 0 to 100 percent. For purposes of comparison, representative CSO

control projects are identified for each secondary system alternative to achieve targets of 75 and 90 percent CSO volume reduction. There will be additional planning and project analysis during the implementation of the selected secondary treatment and CSO control plan.

This supplement presents refined and added information (as described in the following section) on CSO control alternatives for the first four secondary system alternatives, so that all five alternatives can be compared on an equitable basis. Volume III of the November facilities plan identified representative CSO control projects for each of the four secondary system alternatives. Those projects were not selected to achieve the target goals of 75 and 90 percent volume reduction being used for comparisons in this supplement. Instead, representative projects were selected based on the "knee-of-the-curve" concept; that is, representative projects were combined until the cost-benefit curve showed a sharp increase indicating that the benefits were no longer proportional to the added costs. As a result, the combinations of representative projects achieved similar, but not identical, volume reductions for each of the four secondary system alternatives. Also, Volume III did not identify representative projects that could achieve 90 percent CSO volume reduction in the NSA. The CSO alternatives described in Volume III were evaluated further in preparation of this supplement by:

- Identifying representative CSO projects to achieve the target goals of 75 and 90 percent CSO reduction in both the SSA and the NSA.
- ****** Applying refined computer models.
- ****** Applying the newly developed pollutant loading model.

SCOPE OF THE SUPPLEMENT

The scope of the CSO studies performed for this supplement is summarized below:

- Modify the computer models used to predict CSO discharges. Increase the level of detail and update previously used data on the sewage system and drainage areas to enhance the analysis of CSO at individual overflow points.
- Modify the computer models to calculate pollutant loadings at each individual CSO discharge point.
- Evaluate representative CSO projects identified in the November 1985 plan using the modified models.
- Develop and evaluate representative CSO alternatives for the fifth secondary system alternative.
- **Describe** representative CSO control facilities to achieve 75 and 90 percent CSO volume reduction for each of the five secondary system alternatives.
- **Present the costs and pollutant loadings associated with the above CSO control facilities.**
- **Example 2** Compare the CSO control facilities with previously developed evaluation criteria.
- Develop proposed priority of CSO projects for each secondary system alternative.

ORGANIZATION OF THE SUPPLEMENT TO THE PLAN FOR CSO CONTROL

This supplement has been prepared as a summary document. It is intended to inform the decision-makers and the public about the technical and economic aspects of the CSO control alternatives. More detailed information about specific aspects of the planning work is included in a number of technical memoranda and the final EIS.

This document is organized in five chapters. To aid the reader in locating specific information, a brief description of each chapter is presented. The following chapters are included in this volume:

Chapter 1 - Introduction:

This chapter presents the purpose and scope of the effort and an introduction to the contents of the report.

- Chapter 2 CSO Control Alternatives for Secondary System Alternative 5:

 This chapter describes the CSO control alternatives for the fifth secondary system alternative and their costs.
- Chapter 3 Evaluation of CSO Control Alternatives for Secondary System Alternative 5:

 Representative CSO control projects are evaluated and a group of representative CSO projects selected for each configuration of the fifth secondary system alternative.
- Chapter 4 Evaluation of Secondary System Alternatives 1 Through 4:

 This chapter describes the results obtained when refined computer models were applied to CSO control alternatives for the first four secondary system alternatives.
- Chapter 5 Comparison of CSO Control Aspects of Secondary System Alternatives:

 This chapter compares the representative project combinations to achieve various levels of CSO control for each secondary system alternative and the effects on pollutant loadings. Two targets used for comparing the secondary system alternatives are 75 and 90 percent CSO volume reductions.

Chapter 2

CHAPTER 2

CSO CONTROL ALTERNATIVES FOR SECONDARY SYSTEM ALTERNATIVE 5

SECONDARY SYSTEM ALTERNATIVE 5

The supplement to the plan for secondary treatment facilities fully defines the fifth secondary system alternative. The following abbreviated descriptions and Figure 2-1 define the terms used in this volume to identify the three variations of the fifth secondary system alternative evaluated in the supplement to the secondary facilities plan:

XX Large Duwamish--

This alternative would relocate the West Point plant to the Duwamish site, D-9, and the flows would be conveyed through a new interceptor that would generally parallel the Elliott Bay interceptor (EBI).

Large Interbay--

This configuration would relocate the West Point plant to a site at Interbay, and the current West Point flows would be conveyed in the existing EBI and the existing North interceptor (NI).

Split Interbay/Duwamish--

In this alternative, the West Point flow would be split between a treatment facility located at the Duwamish site and a treatment facility at Interbay. As in the above configurations, the West Point plant would be removed or relocated. Southern Service Area (SSA) flows from King Street and to the south would flow to the Duwamish plant.

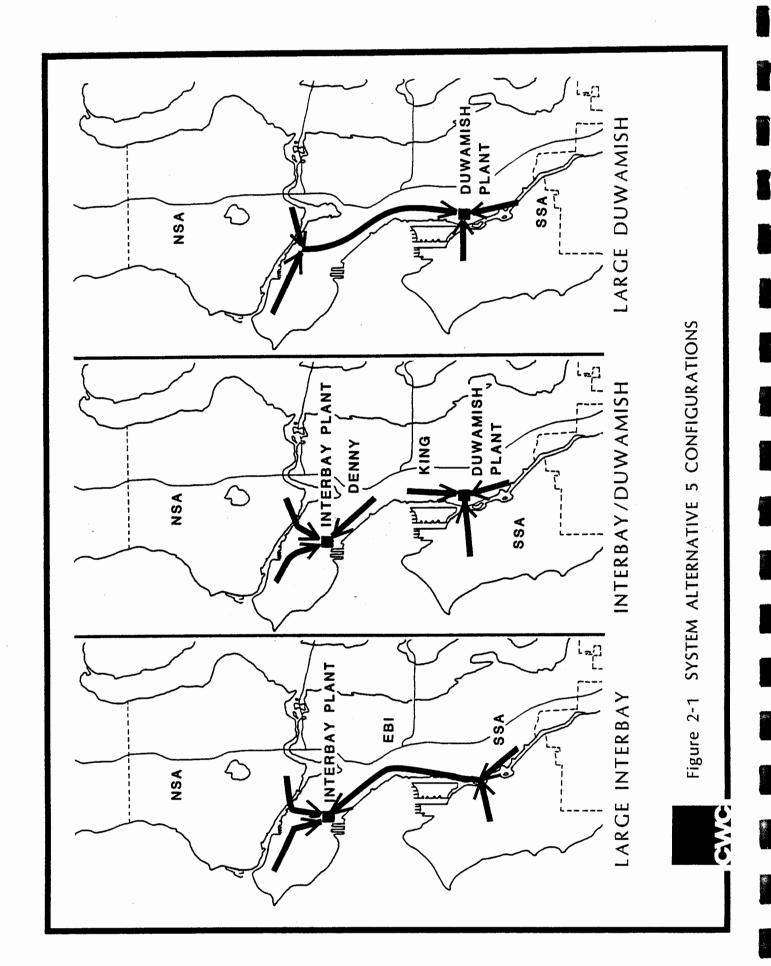
In all variations of the fifth secondary system alternative, sewage flows from the existing Carkeek and Alki treatment plants would be conveyed to the Duwamish and/or Interbay plants for treatment.

CSO CONTROL ALTERNATIVES

Representative CSO Projects Described in the November 1985 Plan

In the November 1985 plan, the following representative CSO projects were described in Volume III as providing the most economical way to achieve 70 to 75 percent reduction in CSO volume:

- Hanford Separation--The stormwater separation project in the Rainier Valley would be completed by installing a new sanitary sewer inside the existing tunnel used to convey combined flows from the valley to the EBI. Reactivation of the Bayview tunnel may provide added CSO reduction and increased cost-effectiveness.
- **CATAD Improvements--Modifications** to the CATAD control system would more fully utilize storage capacity in existing sewers.
- Diagonal Separation—This project would complete the separation of sanitary and storm drainage by installing new sanitary sewers in about 720 acres of combined or partially separated industrial area.



- **Kingdome/Industrial Area Separation--**New sanitary sewers would be constructed to separate the sanitary flows from the storm runoff in about 970 industrial acres connected to combined sewers.
- William University Regulator CSO Control (Greenlake/I-5 Separation)--Storm runoff from the Densmore drain, I-5, Ravenna Park, and outflow from Green Lake would be diverted from the NI system to a new storm drain. The route and discharge location of the storm drain is now under study by Metro.
- Denny CSO Treatment Facility--The substantial CSO from the Denny Way CSO regulator would be conveyed to a new CSO treatment facility where at least the equivalent of primary treatment would be provided. The precise treatment process to be used would be determined in predesign. For use as a representative project, swirl concentrators and microscreens have been used, with treatment effect assumed to be the same as primary Three locations were considered for the treatment plant: under Myrtle Edwards Park; on a site on the land side of the railroad tracks about 1,000 feet from the regulator; and in the vicinity of the Interbay pumping station. At the request of the City of Seattle, the location 1,000 feet from the regulator is used as the basis for the cost estimates in this addendum. These costs are \$3,200,000 higher than the cost of the Denny Way facility located under Myrtle Edwards Park as described in Volume III. CSO treatment plants and marine outfalls, unlike sanitary sewage treatment plants, discharge infrequently. Between discharges, saltwater fills the outfall and marine growths reduce the outflow capacity. To control these growths, the diffusers would be provided with weighted flap valves, and a chlorine solution line would be provided in the outfall to maintain a chlorine residual in the idle outfall pipe. In addition to costs shown in the November 1985 plan, preliminary estimates indicate that an added \$450,000 may be required for odor control equipment comparable to that now being considered in the secondary plan.
- Duwamish CSO Treatment Facility--A CSO treatment facility would be located near the Duwamish pumping station. The treated CSO would be conveyed to Elliott Bay in the vicinity of King Street. The outfall would be treated in a similar manner to that described for the Denny CSO treatment plant. Odor control could add another \$600,000 to the costs shown for this project in the 1985 plan.
- Parallel Fort Lawton Tunnel--A parallel tunnel would allow increased flows to West Point. Because West Point is relocated in all variations of the fifth secondary system alternative, this alternative applies only to secondary system alternatives 1 through 4.
- Washington parking area, was described and evaluated in Volume III of the November 1985 CSO control plan. This option was not recommended in that report, because it was not needed for the levels of CSO control evaluated in Volume III. It is needed if the 75 percent and 90 percent CSO reductions must be met in the Northern Service Area (NSA). The location of the storage will need to be reviewed during predesign because of subsurface conditions and concerns expressed by the University over the site identified in Volume III. Odor control costs could add another \$2,200,000 to the costs shown for this project in the 1985 plan.

Other CSO Control Alternatives

In addition to the CSO projects listed above, the following alternatives were evaluated for secondary system alternative 5.

Enlarged Regional Conveyance and Treatment Capacities--

Secondary system alternative 5 includes new regional interceptors and new regional treatment plants not found in the other four secondary system alternatives. If the new regional conveyance and treatment facilities were increased in size beyond the base case system needed to convey and treat sanitary base flows, CSO would be reduced. To test the economic feasibility of this approach, costs were estimated by the secondary planning team (see Appendix B) to increase the size of the regional facilities to convey and treat the flows associated with design storms 2, 4 and 6. Design storms 1 and 7 were both larger than storm 6 and resulted in peak flows that clearly were not practical to convey or store. The total flows associated with the other design storms and the base case were:

<u>Storm</u>	Peak Flow Rate (mgd)
Base Case	371
2	457
4	682
6	989

For alternatives incorporating larger regional conveyance facilities, one concept considered was to design the treatment plant facilities so that the series operation of the primary clarifiers with the secondary biological treatment plant became parallel operation of the primary clarifiers and biological treatment plant during storm events. In this manner the 371 mgd plant capacity could be doubled to 742 mgd when treating combined sewage. All flows would be treated with screens and grit removal. Flows in excess of 371 mgd would bypass the primary clarifiers to the biological treatment process. An equal amount of primary effluent flow would bypass the biological treatment process. The plant operation would gradually change from a series flow through the process up to 371 mgd; to a mixture of series and parallel operation between 371 mgd and 741 mgd; and ultimately to all parallel flow operation at 742 mgd. For the split Interbay/Duwamish configuration, the Duwamish plant could process up to 250 mgd (125 mgd of CSO). The Interbay plant could process 492 mgd (246 mgd of CSO).

The relative economics of parallel operation can be determined by comparing the costs (see Appendix B) of primary clarifiers associated with the "additional CSO treatment" for the various conveyance levels up to the 371 mgd CSO capacity with the cost of parallel operation. Parallel operation of the treatment plants requires that the pretreatment facilities be enlarged to a capacity greater than that required for secondary treatment only (screening, grit removal). The secondary treatment process proposed by the secondary team is a combination of trickling filters and activated sludge. Trickling filters require pretreatment beyond coarse screening and grit removal since a significant quantity of debris escapes and would accumulate in the trickling filter media. Bypassing the primary clarifiers straight to aeration tanks in activated sludge would be an acceptable practice; but with trickling filters, fine screens are required. When the costs for fine screens are considered, parallel operation is not competitive with the costs shown in Appendix B for added treatment capacity. Thus, costs for added treatment capacity are those defined in Appendix B.

Southern Service Area--

The following projects were developed as alternatives for the comparative targets of 75 percent and 90 percent CSO volume reduction in the SSA.

We of Portions of the EBI for Storage--The large Duwamish configuration would result in abandoning two major interceptor segments on the EBI and NI because new conveyance facilities would be provided. The split Interbay/Duwamish configuration would result in abandoning a segment of the EBI. The secondary planning team is considering several conveyance alternatives to convey flow from Interbay to the south. Some alternatives may use portions of the EBI, eliminating them for storage. Should those options be implemented, substitute CSO control projects would be required to achieve the same level of CSO volume reduction.

In the option maximizing the storage potential in the EBI, flows would be conveyed from the NSA and SSA to the Duwamish site by a deep tunnel. The secondary plan is based on conveying SSA flows via the EBI to a single portal at the Interbay pumping station. At that point, the SSA flows would enter the deep tunnel. In order to use the EBI for storage, several portals or "adits" would be required and are included in the CSO control costs.

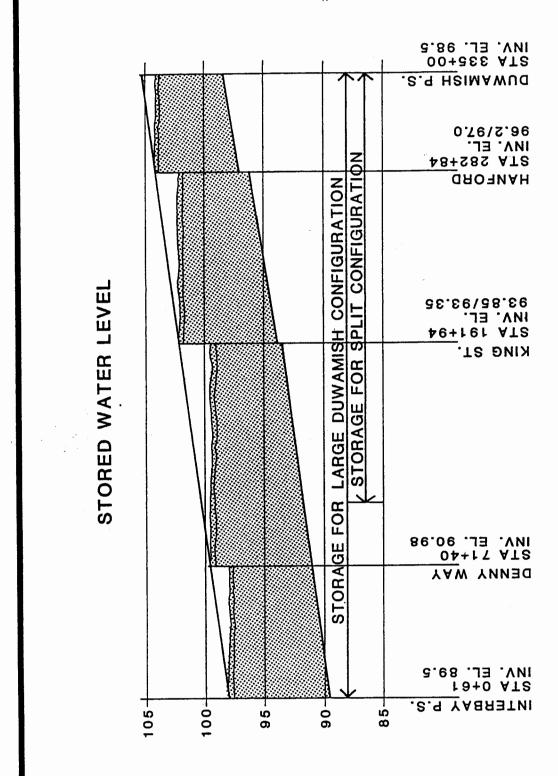
In the large Duwamish configuration, the segment of the EBI from the Interbay pumping station to the Duwamish site would be available for CSO storage. This segment is shown in Figure 2-2. It has been assumed that the EBI would not be surcharged and that bulkheads with control valves would be constructed at Denny Way, South King Street, and Hanford Street. A storage volume of 12.2 MG would be available. Stored flow would be returned to the new south-flowing sewer by gravity.

Also shown in Figure 2-2 is the portion of the tunnel available for storage under the split Interbay/Duwamish configuration. The remaining volume available for storage between Myrtle Edwards Park and Duwamish would be 6.3 MG. A portion of this flow could be returned by gravity; however, the residual below the normal flow line would need to be pumped back to the EBI. A 10 mgd package pumping station is included in the cost estimate. The split Interbay/Duwamish option reverses the flows from King Street south to the Duwamish site. The Pike Street adit north would be conveyed to an Interbay plant. The secondary planning team proposes to convey sewage from King Street south with 36- to 66-inch sewers sized only for base flows. It would be necessary to increase the size of these pipes to 60 to 90 inches, at an increased cost of \$15,000,000, to optimize the CSO benefits of the split plant configuration.

The capital and operating costs for storage under the two configurations are shown in Tables 2-1 and 2-2. The portions of the EBI used for storage would receive flow only intermittently. They would be flushed with fresh water at the end of each storage period in order to control odors between uses. When in use, odor generation would be comparable to the present when wastewater is flowing through the line.

Consideration was also given to storage in an enlarged deep tunnel. The present plan uses 33,000 feet of 114-inch tunnel. A 132-inch tunnel would provide about 7 MG of storage over the conveyance capacity planned. The added cost is estimated to be \$21,000,000, or \$3 per gallon. The storage volume is forecast to reduce CSO volume by 100 MG per year. The unit cost for the enlarged tunnel would be \$210,000 per million gallons of CSO volume reduction. This is higher than most SSA CSO volume reduction projects.

In the split plant alternative, the flows being carried northerly by the Interbay pumping station are based on the same Interbay pumping station capacity (21 mgd) described in Volume II of this supplement.



rigure 2

TABLE 2-1

ESTIMATED COSTS FOR EBI STORAGE, LARGE DUWAMISH CONFIGURATION

CAPITAL COSTS	
Adits from Existing Regulators to Deep Tunnel Bulkheads and Control Weirs Regulator to Deep Tunnel Electrical, Instrumentation and Telemetry Subtotal Inflation to Mid-1988 (23%) Allied Costs (59%) ESTIMATED PROJECT COSTS	\$ 5,200,000 60,000 250,000 — 40,000 \$ 5,550,000 — 120,000 — 400,000 \$10,840,000
OPERATING COSTS	
Labor Treat Stored Water, 600 MG/yr. @ \$300/MG Miscellaneous ESTIMATED ANNUAL O&M COSTS, 1985 ESTIMATED ANNUAL O&M COSTS, 1991 PRESENT-WORTH O&M COSTS	\$ 30,000 180,000 30,000 \$ 240,000 \$ 340,000 \$ 6,960,000
EQUIPMENT REPLACEMENT	\$0
TOTAL PRESENT WORTH	\$17,800,000

TABLE 2-2

ESTIMATED COSTS FOR EBI STORAGE, SPLIT INTERBAY/DUWAMISH CONFIGURATION

CAPITAL COSTS	
Bulkheads and Control Weirs Pumping Station Return to EBI Electrical, Instrumentation and Telemetry Subtotal Inflation to Mid-1988 (23%) Allied Costs (59%) ESTIMATED PROJECT COSTS	\$ 60,000 1,000,000 <u>200,000</u> \$1,260,000 290,000 <u>750,000</u> \$2,300,000
OPERATING COSTS	
Labor Treat Stored Water, 500 MG/yr. @ \$300/MG Miscellaneous ESTIMATED ANNUAL O&M COSTS, 1985 ESTIMATED ANNUAL O&M COSTS, 1991	\$ 55,000 150,000 35,000 \$ 240,000 \$ 340,000
PRESENT-WORTH O&M COSTS	\$6,960,000
EQUIPMENT REPLACEMENT	
Pumping Station, 2010	\$ 375,000
TOTAL PRESENT WORTH	\$9,635,000

Storage Projects in the Kingdome and Diagonal Basins--Storage projects were evaluated as an alternative to separating sewers in these basins. The storage projects were sized to provide approximately the same CSO reductions as the separation projects. The Kingdome (King County Stadium) has a large parking area that may provide space for underground storage facilities. The location of the proposed storage is shown in Figure 2-3. The south section of the parking area was chosen because other areas of the lot are now under consideration for construction of other facilities. Flow into the storage structure would be by gravity, and would be controlled by a new regulator station on the EBI. Flow from storage would be pumped back into the EBI. Figure 2-4 presents a schematic of the facility.

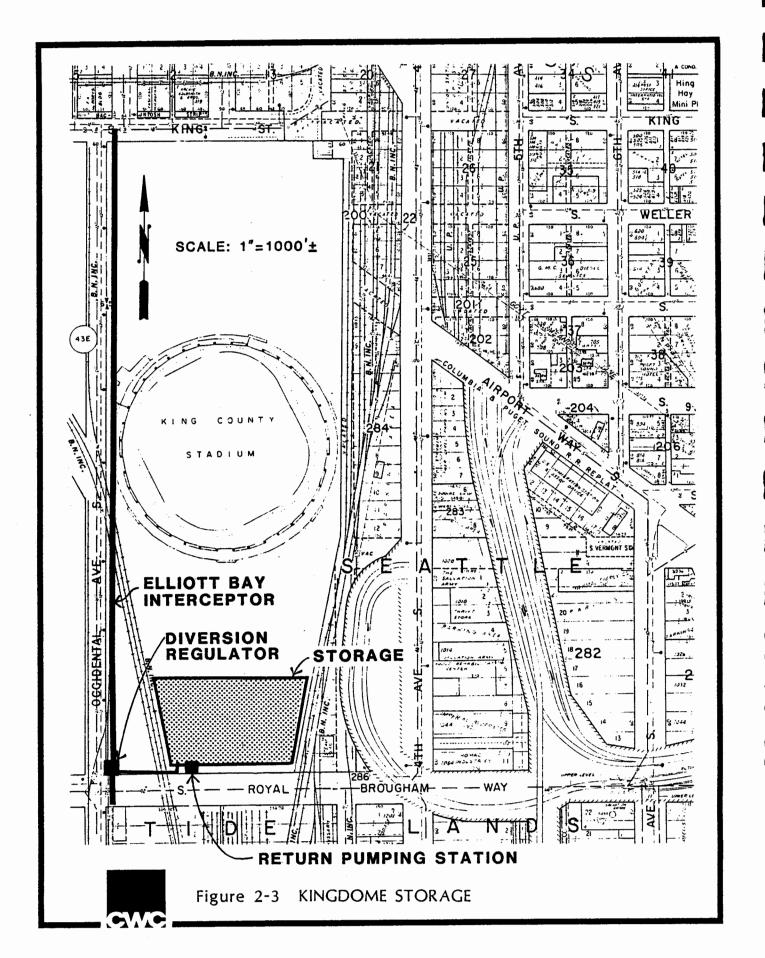
The required 15 MG storage volume would be accommodated in a subsurface structure, with an average water depth of 15 feet and a total area of 135,000 square feet. The structure would be divided into a series of separate chambers, with baffles and control gates to allow sequential filling and draining. Access would be provided to allow washdown and other operation and maintenance. Table 2-3 contains cost estimates for the 15 MG facility, based on cast-in-place concrete construction supported by pilings. Preliminary estimates of potential odor control costs indicate that about \$1,500,000 of added costs might be needed at this location.

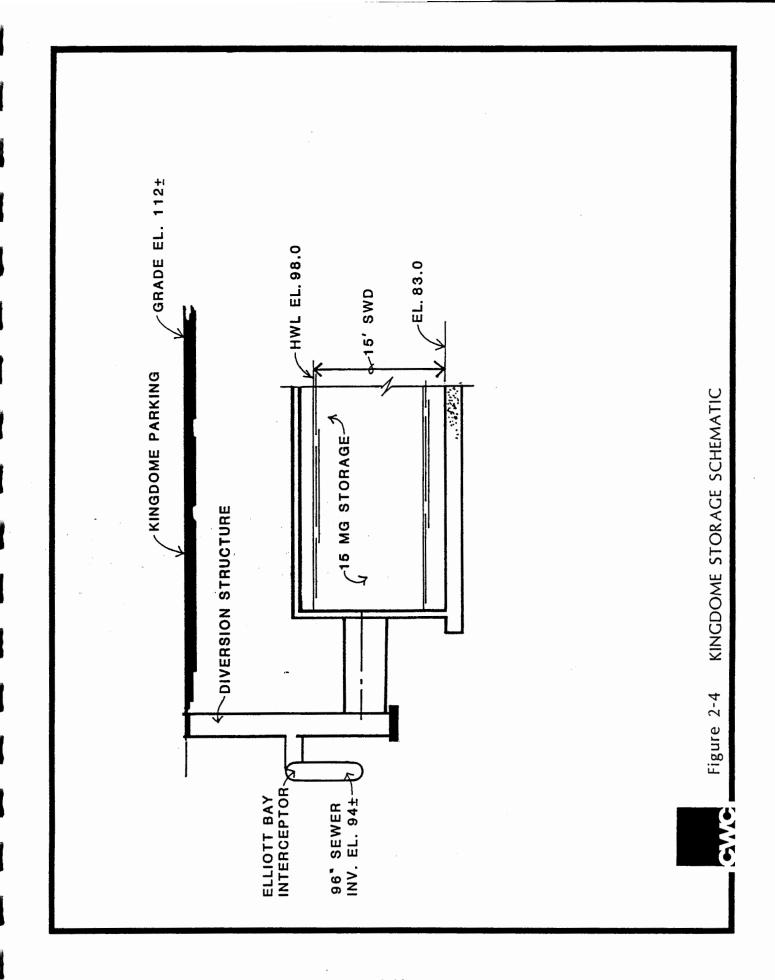
The concept used to evaluate storage in the Diagonal area requires construction of relief sewers along Diagonal Avenue South and a storage facility constructed at the site of the Duwamish pumping station at East Marginal Way South and Diagonal Avenue South. The storage facility would be a 10 MG buried rectangular structure, as shown in Figure 2-5. Flow into and out of the structure would be by gravity. The storage is based on the approximately 8 feet of water surface elevation fluctuation available from the invert of the inlet sewer to the top of the wet well (see Figure 2-6). The high level would be about 10 to 12 feet lower than the existing ground elevation, so the structure would be completely buried, leaving the land above it available for other uses.

The storage basin would be divided into compartments. Flow into the structure would be through a regulator constructed on the lateral pipe connected to the 60-inch interceptor just ahead of the pumping station. An automatic gate would be opened when necessary to allow flows into the storage basin. Each compartment would also be equipped with a gate at its entrance in order to allow controlled sequential filling and draining. The compartments would be filled when the wet well reached its maximum water level. When called for by the system controller, the wet-well level would be allowed to drop, allowing the sewage to be drained from the storage structure. Multiple access points would be incorporated in order to allow periodic washdown and maintenance.

Table 2-4 contains estimated construction and operating costs for the Diagonal Avenue South relief sewer and the 10 MG storage facility. Costs are based on a cast-in-place structure supported by pilings. Odor control costs have been preliminarily estimated as \$1,100,000 for this location and would be in addition to those in Table 2-4.

Alaskan Way Storage--This alternative involves the use of large-diameter (60- to 120inch-diameter) pipes placed under streets along the waterfront between the southern
boundary of Myrtle Edwards Park and South Royal Brougham Way. Figure 2-7 shows the
location of each of the nine segments of the storage pipes. Segments 1 and 9 in-clude
piles to support the storage pipes. Table 2-5 presents the estimated costs. The costs
are equivalent to \$6.30/gallon of storage, about three times the unit cost of most other
storage projects. Because of the high cost, and the disruption that would be caused
during construction, this project was not used as a representative CSO control project.





ESTIMATED COSTS FOR KINGDOME STORAGE

CAPITAL COSTS	
Storage Excavation Dewatering Sheeting Piling Concrete Pavement Replacement Pumping Station Diversion Structure Miscellaneous Site Work Subtotal Inflation to Mid-1988 (23%) Allied Costs (59%)	\$ 1,200,000 450,000 900,000 3,900,000 7,200,000 1,500,000 150,000 2,250,000 \$17,850,000 4,050,000 12,900,000
ESTIMATED PROJECT COSTS	\$34,800,000
OPERATING COSTS Labor Miscellaneous Treatment Costs, 250 MG/yr. @ \$300/MG ESTIMATED ANNUAL O&M COSTS, 1985 ESTIMATED ANNUAL O&M COSTS, 1991	\$ 120,000 9,000 75,000 \$ 204,000 \$ 289,000
PRESENT-WORTH O&M COSTS	\$ 5,920,000
EQUIPMENT REPLACEMENT	
Pumping Station	\$ 375,000
TOTAL PRESENT WORTH	\$41,095,000

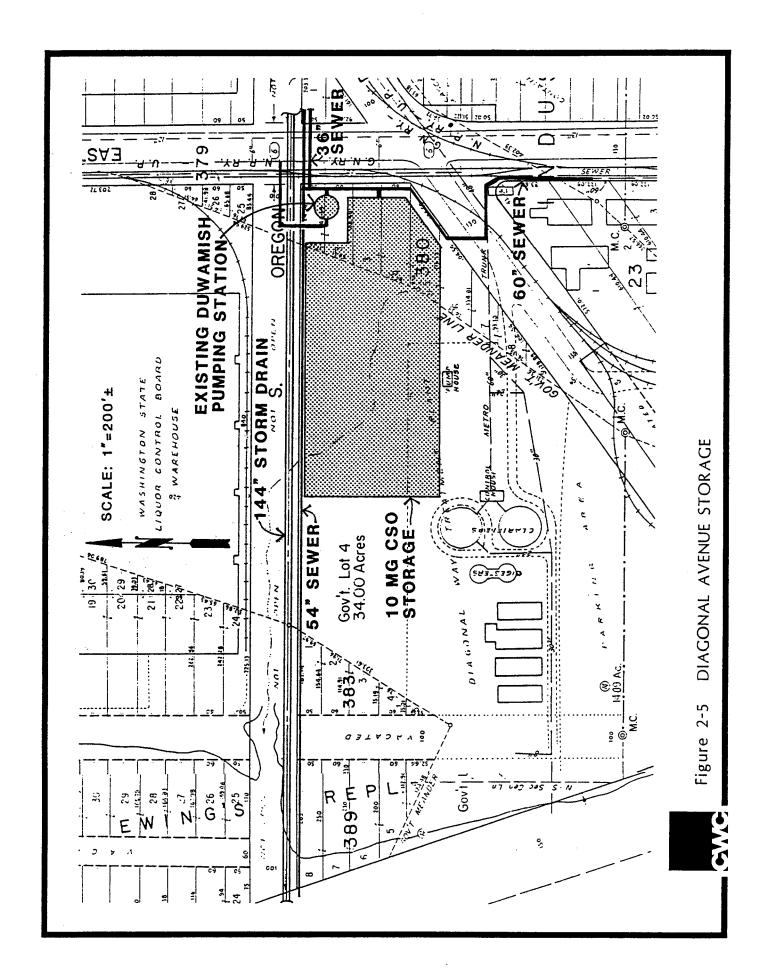


Figure 2-6 DIAGONAL STORAGE SCHEMATIC

ESTIMATED COSTS FOR DIAGONAL STORAGE, 10 MG

CAPITAL COSTS	
Storage10 MG	
36-Inch Gravity Sewer	\$ 650,000
Dewatering	400,000
Excavation	900,000
Piling	1,800,000
Sheeting	500,000
Concrete	9,000,000
Regulator	50,000
Site Work	1,000,000
Subtotal	\$14,300,000
Inflation to Mid-1988 (23%)	3,290,000
Allied Costs (59%)	10,400,000
ESTIMATED PROJECT COSTS	\$27,990,000
OPERATING COSTS	
Labor	\$ 20,000
Miscellaneous	10,000
Treatment Cost, 100 MG/yr. @ \$300/MG	30,000
ESTIMATED ANNUAL O&M COSTS, 1985	\$ 60,000
ESTIMATED ANNUAL O&M COSTS, 1991	\$ 85,000
PRESENT-WORTH O&M COSTS	\$ 1,740,000
EQUIPMENT REPLACEMENT	\$0
TOTAL PRESENT WORTH	\$29,730,000
,	

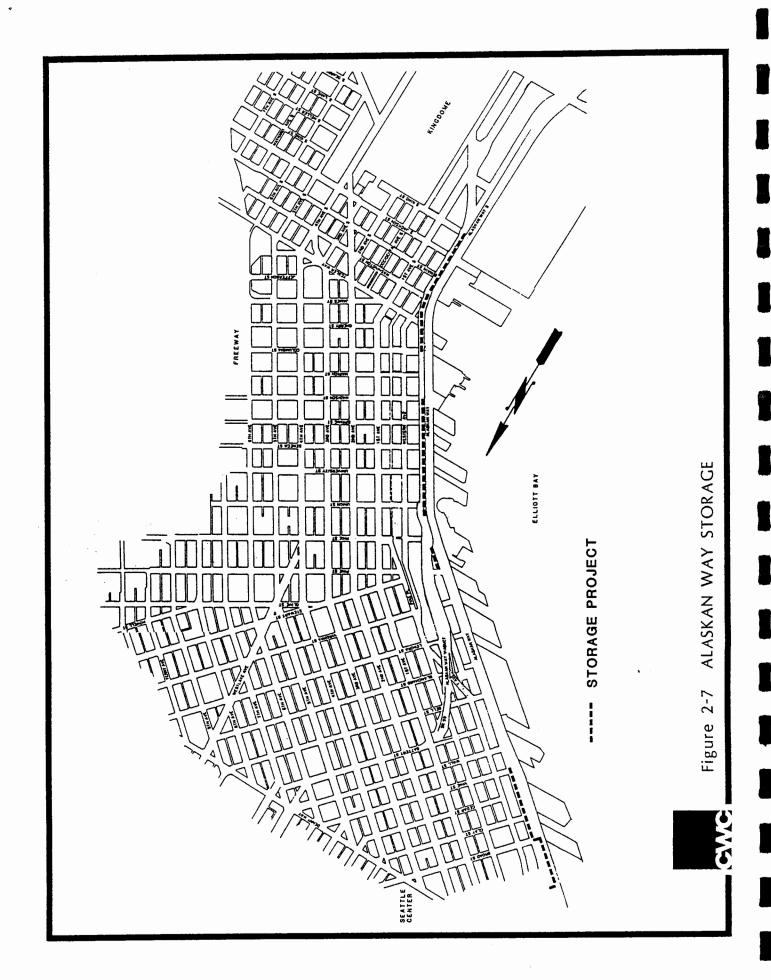


TABLE 2-5 ESTIMATED COSTS FOR ALASKAN WAY STORAGE

Section Number (N Storage Location (Upstream to Downstream)	Storage Configuration	Length <u>(feet)</u>	X-Section <u>Area (ft²)</u>	Volume (X10 ⁶ Gal)	Cost (\$1988)
 -	Vine St. Diversion Str. to Bay St. EBI	120" dia. RCPnew alignment in Alaskan Way	1881	74.55	1.049	\$ 5,496,000
~	Pine St. to Pike St.	60" dia. RCP replacing existing 15" RCP City sewer east of RR tracks along Alaskan Way	356	17.63	0.047	470,000
m	University St. Diversion Str. to Pike St.	96" dia. RCP replace existing 18" dia RCP City sewer under Viaduct	902	47.08	0.249	1,491,000
4	Western Ave. to University St. Diversion Str.	Twin 72" dia. RCP in University St. One replaces existing 30" dia. City sewer. Other is par- allel to the south	340 (165+ 170)	25.86	0.066	539,000
'n	Madison St. upstream of Diversion Str. to Univ. St. Diversion Str.	84" dia. RCP parallel to exist- ing 18" dia. RCP Metro sewer under Viaduct	885	35.71	0.236	1,635,000
•	Madison St. pre- Diversion Str. to Columbia St.	Twin 72" dia. RCP east of Viaduct	1210 (2-605)	25.86	0.256	1,917,000
~	Columbia St. to Yesler Way	84" dia. RCP under Viaduct parallel to 12" dia. RCP Metro sewer (95' of 72" dia. at Columbia St.)	403 95 - 72" dia. 308-84" dia.	25.86	0.1000	720,000
∞	Yesler Way to Washington St. Diversion Str.	84" dia. RCP to replace 12" dia. City sewer under Viaduct	300.	35.71	0.080	554,000

Cost (\$19 <u>88)</u>	\$ 2,132,000	\$14,954,000
Volume (X10 ⁶ Gal)	0.295	2.378
X-Section <u>Area (ft</u> 2)	11.12 35.71 47.08	TOTAL
Length <u>(feet)</u>	955 60' of 48" dia., 251' of 84" dia., 634' of 96" dia.	
Storage Configuration	84" & 96" dia. RCP parallel to existing 12" dia. City sewer under Viacuct	
Section Storage Location Number (Upstream to Downstream)	Washington St. to King St.	
Section Number (0-	

TABLE 2-5 (Continued)

Duwamish CSO Treatment--There are several options for providing CSO treatment near the Duwamish waterway. When the new regional sewers are increased in capacity to convey more combined sewage (flows greater than base flows) to the treatment plants, the increases in primary clarifier surface area shown in Appendix B will provide added capacity for CSO treatment. For the base case alternative (sewers sized for base flows) with the large Duwamish secondary treatment plant, the parallel primary treatment-secondary treatment configuration (using fine screens to protect the TF/SG process) could be used to treat up to an additional 371 mgd of CSO over and above the base sewage flow. In predesign, other treatment options for added CSO flow should be evaluated. Increased conveyance facilities to and from the plant would be required. With the Duwamish plant under the split Interbay/Duwamish configuration, an additional 125 mgd of CSO could be treated. With no Duwamish plant, a separate CSO treatment facility at Duwamish would be required. The outfall from a Duwamish CSO plant must be constructed in conjunction with either the secondary plant outfall or a separate outfall to Elliott Bay.

	LARGE <u>INTERBAY</u>	LARGE <u>DUWAMISH</u>	SPLIT <u>INTERBAY/DUWAMISH</u>
Plant	Separate CSO Plant at Duwamish	Added Treatment at Duwamish Secondary Plant for CSO	Added Treatment at Duwamish Secondary Plant for CSO
Outfall	To Elliott Bay	Enlarge Secondary Outfall	Enlarge Secondary Outfall
CSO Capaci	ty 100 mgd	371 mgd	125 mgd

The costs for the various CSO treatment options for the base case sewer sizing alternative at the Duwamish area, are shown in Table 2-6.

Alternative locations for the CSO treatment plant are available. Sites to the north (near Hanford or the Kingdome) offer a potential saving by reducing the length of the outfall and new influent sewers, and should be considered in predesign if a system 5 alternative with regional sewers sized for base flows is selected.

Northern Service Area--

The following projects were developed as representative alternatives for meeting the comparative targets of 75 percent and 90 percent CSO volume reduction in the NSA.

Storage Projects in the NSA--The potential for storage projects beyond those evaluated in the November 1985 plan was evaluated, and five projects were developed for consideration for reaching 90 percent CSO reduction:

North Interceptor Storage--In the large Duwamish alternative, the portion of the NI downstream of the junction with the EBI would be abandoned. All flows east (upstream) of the EBI would be conveyed south from that point. All flows west (downstream) of the EBI would be conveyed back to that junction in new pipelines.

TABLE 2-6
ESTIMATED COSTS FOR CSO TREATMENT AT DUWAMISH
WHEN SEWER SYSTEM SIZED FOR BASE FLOWS

Duwamish CSO Costs for Secondary System Alternative 5 (\$1,000) Large Large Split Interbay/ <u>Interbay</u> Duwamish Duwamish CAPITAL COSTS Incoming Sewers 9,200 3,622 10,682 Influent Pumping 1,750 4,400 4,400 Treatment Plant @ Duwamish 21,970 5,000 9,000 Effluent Pumping 7,378 7,378 Outfall 11,910 5,100 11,910 Subtotal 44,830 25,500 43,370 Inflation to Mid-1988 (23%) 55,140 31,400 53,300 Allied Costs (59%) 32,530 18,500 31,500 **ESTIMATED PROJECT COSTS** 87,670 49,900 84,800 **OPERATING COSTS** Labor 90 68 80 Miscellaneous 13 15 28 Treatment 20 20 20 ESTIMATED ANNUAL O&M, 1988 123 103 128 ESTIMATED ANNUAL O&M, 1991 177 148 160 PRESENT-WORTH O&M COSTS 3,780 3,170 3,430 **EOUIPMENT REPLACEMENT** 2,250 500 1,500 TOTAL PRESENT WORTH (1988) 93,700 53,600 89,730

Approximately 13,700 feet of 138-inch and 144-inch pipe, including the Fort Lawton tunnel, would be isolated for this project, as shown in Figure 2-8. The available storage, assuming use of the entire pipe volume, is 11.2 MG. A 24-inch pipe would be laid inside the storage pipe so that the volume stored could be pumped out to the large Duwamish treatment plant when capacity was available in the conveyance system.

Two points of concern have been expressed about using the abandoned Fort Lawton tunnel for storage:

- There is concern that the Fort Lawton tunnel might not be structurally capable of taking hydraulic surge pressures associated with pump failure, or sudden velocity changes when used for effluent transport. If used for storage, the sewer would be statically surcharged by 4 feet at its lower end, or a series of internal check dams would be required to avoid surcharging the pipe. Surcharging the sewer 4 feet would represent 250 pounds of internal pressure per foot of pipe, or the equivalent of about 2 feet of soil cover over the pipe to offset the uplift force. The concern about surcharging addresses dynamic surges only and does not apply to use of the abandoned sewer for storage, with occasional small static surcharges.
- There is concern that the wet-dry exposure to the brick and mortar would cause mortar to fail and bricks to come loose. The brick tunnel invert lies roughly at sea level. Groundwater levels are at the same level or higher. At present the crown of the sewer is exposed to air, but in a 100 percent relative humidity environment. Should the groundwater not be sufficient to keep the bricks and mortar wet at all times, it might be necessary to retain a pool of water in the sewer to maintain a moist environment.

The total present worth of the project, shown in Table 2-7, is \$7,560,000. Should it be decided that lining the tunnel with an interior steel plate is required, the associated project costs are estimated to be \$15,000,000 more.

Dexter Regulator--A storage site in the area draining toward the Dexter regulator station was proposed in the November 1985 CSO control plan. That storage project, however, called for transfer of stored combined sewage to the EBI via the Lake Union tunnel. Since the capacity of the tunnel is completely used during some storms, a second site was sought that did not use the tunnel.

The alternative storage project developed in this task would provide 2.5 MG of volume immediately adjacent to the Dexter regulator in the block bounded by Dexter Avenue North and 8th Avenue North, and Garfield and Galer Streets, as shown in Figure 2-9. The underground storage facility would be gravity-fed, using a diversion structure on the CSO outfall on Galer Street. When capacity was available in the Central interceptor (CI), the stored combined sewage would be pumped back into the interceptor at an existing manhole in Garfield Street.

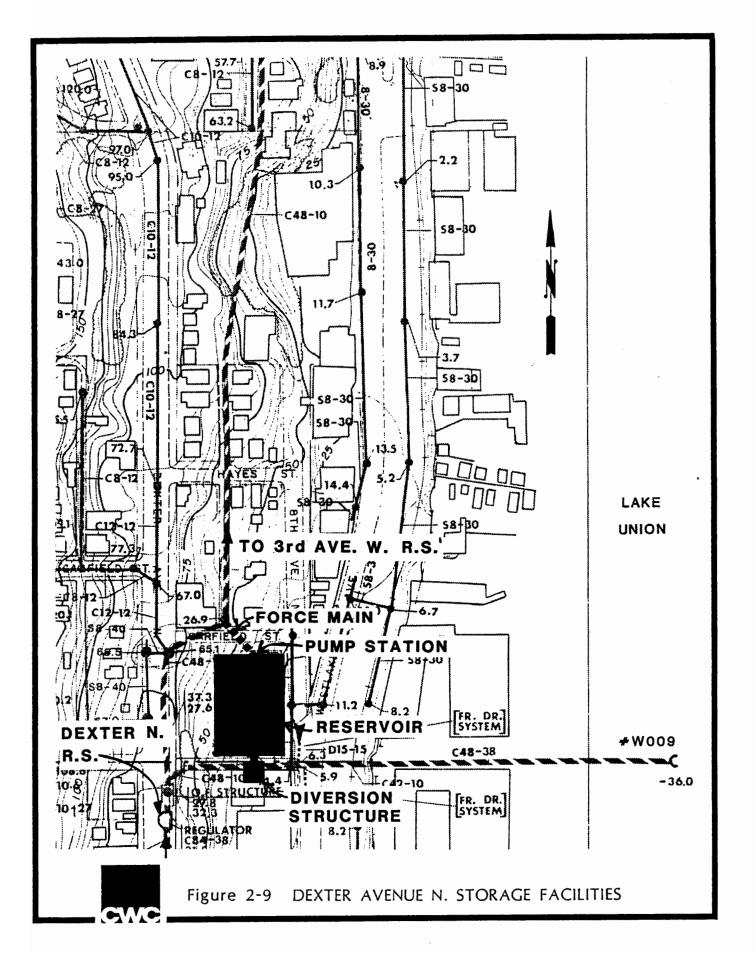
The total present worth of the project is \$6,480,000, as shown in Table 2-8.

LENGTH AND DIAMETER OF PIPE AVAILABLE FOR STORAGE IN NORTH INTERCEPTOR DOWNSTREAM OF EBI Figure 2-8

TABLE 2-7

ESTIMATED COSTS FOR 11.2 MG STORAGE IN NORTH INTERCEPTOR DOWNSTREAM OF EBI

CAPITAL COSTS	
Lay 24-Inch Pipe Inside North Interceptor Pumping Station, 6 mgd Miscellaneous Subtotal Inflation to Mid-1988 (23%) Allied Costs (59%)	\$1,640,000 900,000 <u>460,000</u> \$3,000,000 696,000 <u>2,180,000</u>
ESTIMATED PROJECT COSTS	\$5,870,000
OPERATING COSTS	
Labor Miscellaneous Treatment Cost, 60 MG/yr. @ \$300/MG ESTIMATED ANNUAL O&M COSTS, 1985 ESTIMATED ANNUAL O&M COSTS, 1991	\$ 20,000 10,000 <u>18,000</u> \$ 48,000 <u>68,000</u>
PRESENT-WORTH O&M COSTS	\$1,390,000
EQUIPMENT REPLACEMENT	
Pumping Station	\$ 300,000
TOTAL PRESENT WORTH	\$7,560,000



ESTIMATED COSTS FOR 2.5 MG STORAGE NEAR DEXTER REGULATOR

CAPITAL COSTS	
Storage Excavation Dewatering Piling Concrete Diversion Structure Pumping Station Piping Site Work Subtotal Inflation to Mid-1988 (23%) Allied Costs (59%)	\$ 150,000 70,000 330,000 1,810,000 35,000 480,000 20,000 10,000 \$2,905,000 668,000 2,107,000
ESTIMATED PROJECT COSTS	\$5,680,000
OPERATING COSTS Labor Miscellaneous Treatment Cost, 5 MG/yr. @ \$300/MG ESTIMATED ANNUAL O&M COSTS, 1985 ESTIMATED ANNUAL O&M COSTS, 1991	\$ 10,000 10,000
PRESENT-WORTH O&M COSTS	\$ 624,000
EQUIPMENT REPLACEMENT TOTAL PRESENT WORTH	\$ 180,000 \$6,484,000

3rd Avenue West Weir Storage--Since overflows occurring at the 3rd Avenue West weir are among the largest in the NSA, an alternative storage site was developed to reduce CSO at that point. The proposed site, providing 2.7 MG of storage, would be located beneath Wallace Field in the eastern portion of the block bounded by Queen Anne Avenue, West Nickerson Street, 3rd Avenue West, and the Lake Washington Ship Canal, as shown in Figure 2-10.

The concrete storage structure would be constructed beneath the existing playing field, and the field would be restored to its present condition at the end of construction. The 2.7 MG facility would be gravity-fed from a diversion structure in the CI in Nickerson Street. When capacity became available following a storm, the stored combined sewage would be pumped through a new force main to a new connection with the interceptor between the 3rd Avenue West weir and the junction structure joining the Central and North interceptors.

The total present worth of the project is \$8,370,000, as shown in Table 2-9.

Ballard Regulator Storage--Storage sites were evaluated near both overflow points on the Ballard trunk. The first of these is located near the Ballard regulator station. The 2.5 MG underground structure would be located in the block bounded by Ballard Avenue N.W., Shilshole Avenue N.W., N.W. Dock Place, and 17th Avenue N.W., as shown in Figure 2-11. The proposed site is presently occupied by an operating sheet metal works, several vacant warehouses, a vacant office building, and a parking lot. When completed, the surface could be used for parking, as a park, or a combination of both.

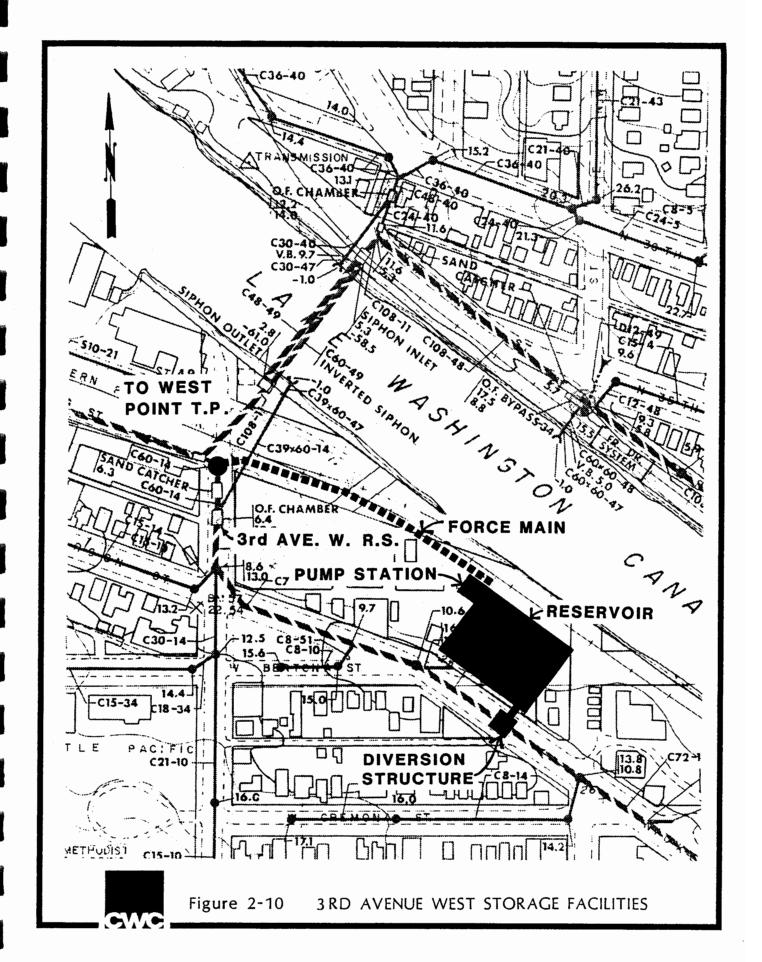
The storage facility would be gravity-fed and would be divided into separate chambers, with baffles and control gates to allow sequential filling and draining. The diversion structure for filling the facility would be located on the Ballard trunk in Shilshole Avenue N.W., adjacent to the storage site. When capacity was available in the trunk, the contents of the storage structure would be pumped into the trunk at a point between the regulator station and the forebay of the Ballard siphon.

The total present worth of the project is \$7,900,000, as shown in Table 2-10.

Ballard No. 1 Weir Storage--Overflows from the Ballard No. 1 weir are slightly less than 10 percent of the total NSA overflow volume. A storage alternative was developed in the vicinity of Ballard No. 1 to reduce CSO from that location. The proposed 2.0 MG storage facility would be an underground structure located in the western half of the block bounded by N.W. Ballard Way, 46th Avenue N.W., 11th Avenue N.W. and 9th Avenue N.W., as shown in Figure 2-12. The proposed site is presently part of the parking lot for the Washington State Department of Social and Health Services, and could be restored to that same use following construction.

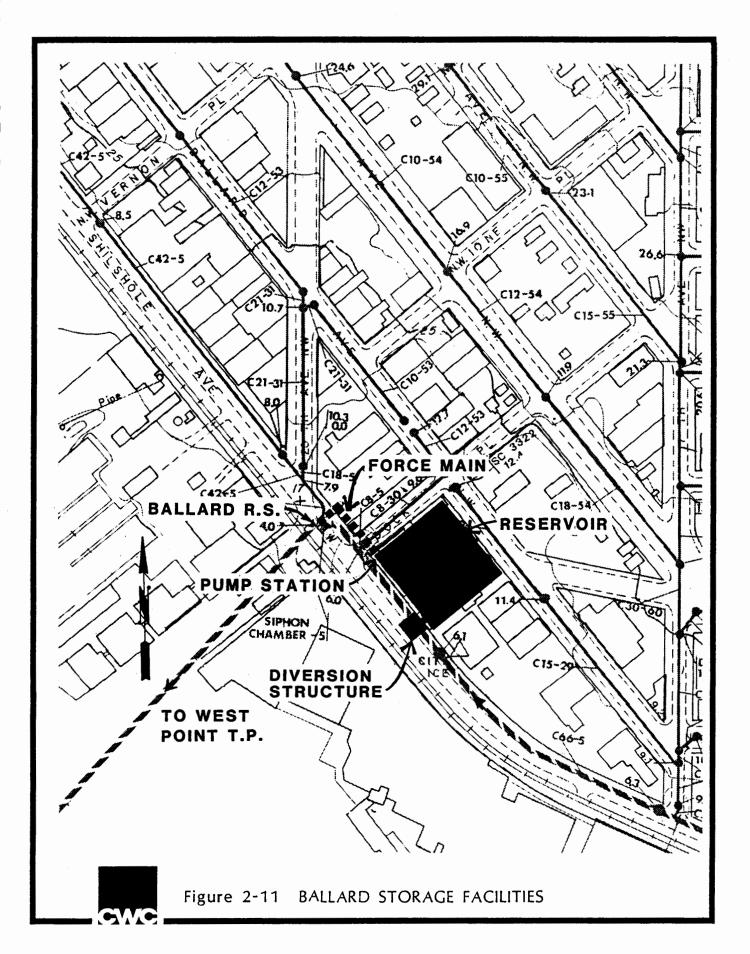
The storage facility would be gravity-fed and would be divided into separate chambers, with baffles and control gates to allow sequential filling and draining. Flow would be diverted to storage from a new structure located on the Ballard trunk. When capacity was available in the trunk, the contents of the storage facility would be pumped back to the Ballard trunk through a new 18-inch force main. The force main would reconnect with the trunk just downstream of the Ballard No. 1 weir.

The total present worth of the project is \$6,820,000, as shown in Table 2-11.



ESTIMATED COSTS FOR 2.7 MG STORAGE NEAR 3RD AVENUE WEST WEIR

CAPITAL COSTS	
Storage Excavation Dewatering Piling Concrete Diversion Structure Pumping Station Piping Site Work Subtotal Inflation to Mid-1988 (23%) Allied Costs (59%)	\$ 260,000 100,000 420,000 2,390,000 45,000 500,000 80,000
ESTIMATED PROJECT COSTS	\$7,480,000
OPERATING COSTS	
Labor Miscellaneous Treatment Cost, 14 MG/yr. @ \$300/MG ESTIMATED ANNUAL O&M COSTS, 1985 ESTIMATED ANNUAL O&M COSTS, 1991	\$ 10,000 10,000 <u>4,000</u> \$ 24,000 \$ 34,000
PRESENT-WORTH O&M COSTS	\$ 703,000
EQUIPMENT REPLACEMENT	\$ 190,000
TOTAL PRESENT WORTH	\$8,370,000

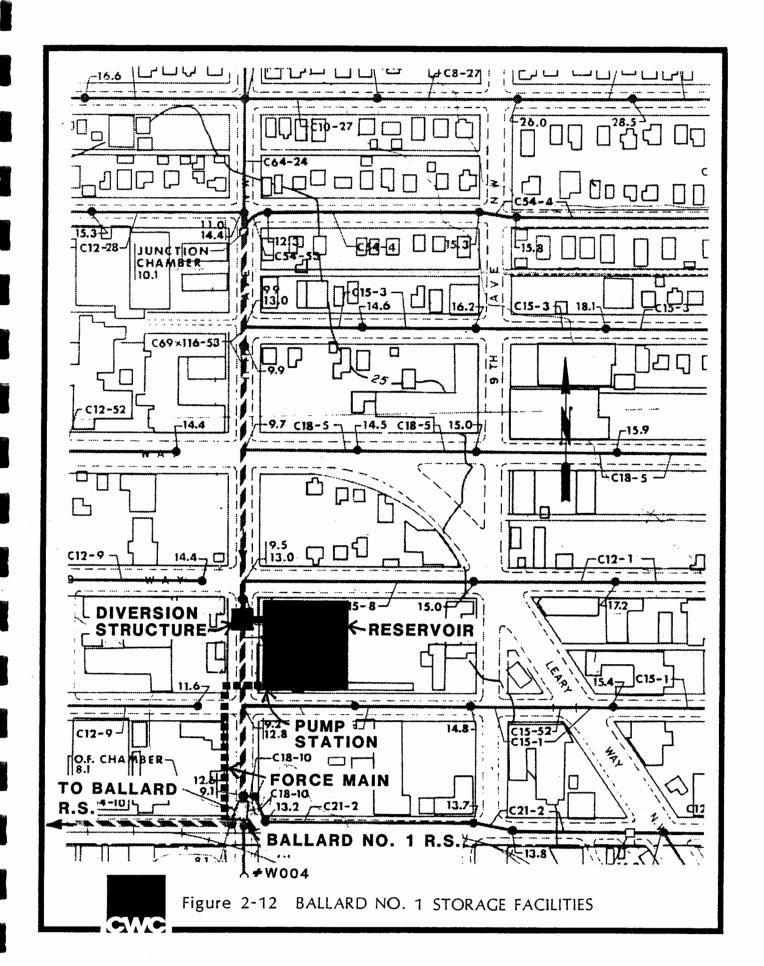


ESTIMATED COSTS FOR 2.5 MG STORAGE NEAR BALLARD REGULATOR

CAPITAL COSTS Storage Excavation \$ 220,000 Dewatering 90,000 Piling 400,000 Concrete 2,370,000 **Diversion Structure** 45,000 **Pumping Station** 480,000 **Piping** 24,000 Site Work 15,000 Subtotal \$3,644,000 Inflation to Mid-1988 (23%) 838,000 Allied Costs (59%) 2.644,000 **ESTIMATED PROJECT COSTS** \$7,126,000 **OPERATING COSTS** Labor 10,000 Miscellaneous 6,000 Treatment Cost, 15 MG/yr. @ \$300/MG 4,500 20,500 ESTIMATED ANNUAL O&M COSTS, 1985 ESTIMATED ANNUAL O&M COSTS, 1991 \$ 29,000 PRESENT-WORTH O&M COSTS \$ 596,000 **EOUIPMENT REPLACEMENT** \$ 180,000

TOTAL PRESENT WORTH

\$7,900,000



ESTIMATED COSTS FOR 2.0 MG STORAGE NEAR BALLARD NO. 1 WEIR

CAPITAL COSTS	
Storage	
Excavation	\$ 190,000
Dewatering	80,000
Piling	330,000
Concrete	2,000,000
Diversion Structure	47,000
Pumping Station	420,000
Piping	48,000
Site Work	10,000
Subtotal	\$3,125,000
Inflation to Mid-1988 (23%)	719,000
Allied Costs (59%)	2.268.000
ESTIMATED PROJECT COSTS	\$6,112,000
OPERATING COSTS	
Labor	\$ 10,000
Miscellaneous	6,000
Treatment Cost, 10 MG/yr. @ \$300/MG	3,000
ESTIMATED ANNUAL O&M COSTS, 1985	\$ 19,000
ESTIMATED ANNUAL O&M COSTS, 1991	\$ 27,000
PRESENT-WORTH O&M COSTS	\$ 552,000
EQUIPMENT REPLACEMENT	\$ 160,000
TOTAL PRESENT WORTH	\$6,820,000

EBI-NI Junction Storage—A sixth storage project was considered but eliminated from consideration as a recommended project. The storage facility would have consisted of 20 MG of CSO storage in four 5 MG pre-cast circular concrete tanks in the vicinity of West Emerson Street and 15th Avenue West. To be cost-effective, the complete facility, including a pumping station, would have to be above ground. The aesthetic impact of four 200-foot-diameter, 20-foot-high storage tanks in this location in the large Duwamish alternative outweighed the small cost advantage of the project over a combination of other separation and storage projects.

The costs for the five NSA storage projects shown above do not include facilities for scrubbing or carbon adsorption of off gases. Should any of these projects be selected, careful consideration of odor control designs should be made in the predesign work.

Added North Interceptor Capacity--Additional information was evaluated to reassess the potential for reducing CSO in the NSA by enlarging portions of the NI. Consideration was given to a parallel Fremont siphon, raising the 3rd Avenue West weir, enlarging 4,000 feet of the CI downstream of the Dexter regulator, and enlarging 1,800 feet of the S.W. Lake Washington interceptor (LWI) downstream of the Montlake regulator.

<u>Fremont Siphon Parallel</u>--A 42-inch third barrel was considered in the November 1985 plan, but was eliminated as an alternative when no CSO benefit (reduction) was found from SACRO model runs.

When added to the existing 48-inch and 60-inch parallel siphons, the third barrel would add approximately 20 percent to the capacity of the Fremont siphon if wastewater flows had reached weir crest levels at both the North Canal Street weir and the 3rd Avenue West weir.

The North Canal Street weir is in the NI, 530 feet upstream of the forebay of the Fremont siphon. The 3rd Avenue West weir is in the CI, but is only 100 feet upstream of its junction with the NI. In addition, the distance from the junction of the North and Central interceptors upstream to the afterbay of the Fremont siphon is only 180 feet. If flows exceed downstream conveyance capacities, overflows occur at the 3rd Avenue West weir. If the capacity of the Fremont siphon were increased, the higher flows to the lower reaches of the NI would raise the water level at the junction of the North and Central interceptors. The higher water level in the NI would increase water levels at the 3rd Avenue West weir, resulting in higher overflows there.

The existing combined capacity of the Fremont siphon and the CI is over 330 mgd. This exceeds the non-surcharged downstream capacity of the NI. An increase in the capacity of the Fremont siphon would, therefore, also require increased downstream capacity. Planning for secondary system alternative 5 is based upon the same 300 mgd of conveyance for NSA flows used in secondary system alternatives 1 through 4.

The combination of hydraulic impacts on the 3rd Avenue West weir, increased conveyance capacity required between the Fremont siphon and the junction with the EBI, and the 300 mgd conveyance capacity from the NSA effectively eliminate the parallel Fremont siphon from consideration as an alternative.

Raised 3rd Avenue West Weir--A second alternative described in the November 1985 CSO control plan report was raising the 3rd Avenue West weir by 1.1 feet or 1.4 feet, depending on other alternatives implemented simultaneously.

Raising the 3rd Avenue West weir would reduce overflow volumes at that point; however, the higher water level would reduce the head available for conveying flow through the Fremont siphon. Hydraulic calculations indicate that raising the 3rd Avenue West weir by 1.4 feet would require construction of a 42-inch parallel Fremont siphon to maintain the present capacity of the siphon during storm flow conditions. The combination of raising the 3rd Avenue West weir and adding a third pipe at the Fremont siphon would be a viable option to increase the NI capacity; however, downstream restrictions would result in merely transferring this overflow downstream.

Central Interceptor Downstream of Dexter Regulator Station--The 4,000 feet of the CI upstream of the Dexter regulator station consists of 84-, 66-, and 60-inch pipe. The first 4,000 feet of pipe downstream of the regulator consists of 48- and 54-inch pipe. The smaller downstream pipe acts as a bottleneck, causing overflows into Lake Union from the Dexter regulator at Galer Street.

This project would replace the 4,000 feet of downstream pipe (48-inch and 54-inch) with 60-inch pipe. This change would essentially double the capacity of this portion of the CI from approximately 36 mgd to 72 mgd. The location of the replacement would be along Dexter Avenue North from Galer Street north to Halladay Street, as shown in Figure 2-13.

Under present operating conditions, this project would only add to overflows downstream at the 3rd Avenue West weir. Therefore, removal of this bottleneck could only be implemented with projects that would relieve capacity in the NI.

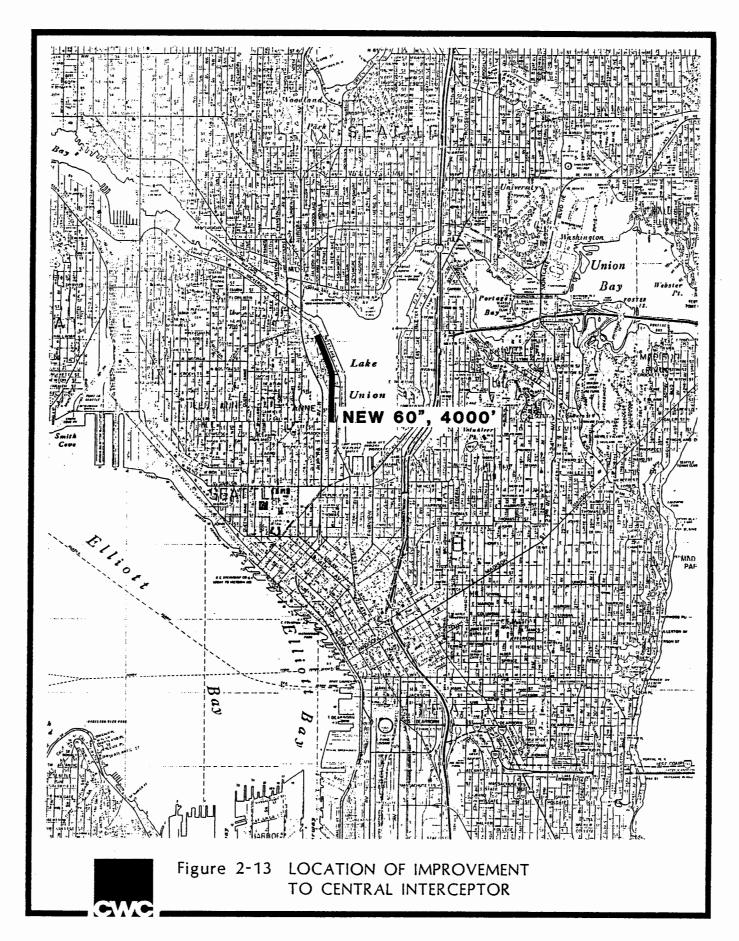
A breakdown of the total project cost (\$5,280,000) is provided in Table 2-12.

S.W. Lake Washington Interceptor Downstream of Montlake Regulator Station--The 3,000 feet of the LWI upstream of the Montlake regulator station consists of 114-inch sewer, a double-barrelled (42-inch and 108-inch) siphon, and 90-inch pipe. The 1,800 feet of pipeline downstream of the Montlake regulator, to the junction with the NI, consists of a single 48-inch siphon under the Montlake Cut, and 1,100 feet of 48-inch pipe. The smaller downstream line acts as a bottleneck in the LWI system, causing overflows from the Montlake regulator into the Montlake Cut, between Union Bay and Portage Bay.

This project would add a parallel 36-inch siphon under the Montlake Cut and a parallel 36-inch pipeline from the end of the siphon to the junction with the NI. This change would increase the present capacity of the system to about 85 mgd. The parallel siphon and sewer would be installed next to the existing line, under the Montlake Bridge and along N.E. Pacific Street to the NI.

This project would only add to overflows downstream along the NI. Therefore, removal of this bottleneck could only be implemented with projects that would provide capacity for the higher LWI flows.

A breakdown of the total project cost (\$2,280,000) is provided in Table 2-13.



ESTIMATED COSTS FOR INCREASED CENTRAL INTERCEPTOR CONVEYANCE CAPACITY

CAPITAL COSTS		
60" Sewer - 4,000 Feet Pavement Cutting & Repair, Traffic Control, Utilities Interference Subtotal, 1985 Construction Cost Inflation to Mid-1988 (23%) Subtotal, 1988 Construction Cost Allied Costs (59%)	\$1,440 _1,260 \$2,700 _620 \$3,320 _1,960	0,000 0,000 0,000 0,000
ESTIMATED PROJECT COSTS	\$5,280	,000
OPERATING COSTS	\$	0
EQUIPMENT REPLACEMENT	\$	0
TOTAL PRESENT WORTH	\$5,280	,000

ESTIMATED COSTS FOR INCREASED MONTLAKE SIPHON AND INTERCEPTOR CAPACITY

CAPITAL COSTS	
36" Siphon 36" Sewer Siphon Junction Structure Modifications (2) Modifications to Junction Structure @ North Interceptor Subtotal, 1985 Construction Inflation to Mid-1988 (23%) Subtotal, 1988 Construction → Allied Costs (59%)	\$ 500,000 440,000 170,000
ESTIMATED PROJECT COSTS	\$2,280,000
OPERATING COSTS	\$ 0
EQUIPMENT REPLACEMENT	<u>\$</u> 0
TOTAL PRESENT WORTH	\$2,280,000

<u>Summary</u>--The alternatives considered for added NI capacity would, at best, merely relocate the CSO discharges and would not reduce CSO in the NSA. Thus, these alternatives were not used as representative CSO control projects.

*** NSA Separation Projects--Fourteen potential separation projects were considered that, when used in conjunction with previously identified NSA CSO control projects, could be used to reach 75 percent or 90 percent NSA CSO reduction. The following projects were evaluated (see Figure 2-14 for locations of projects):

1. Install 84-Inch Harrison Street Tunnel

Description--A large area of the residential Madrona basin has been partially separated, but has been reconnected to the combined sewers. This project would complete the partial separation project by installing an 84-inch tunnel to carry the separated stormwater for discharge into Lake Washington. This project was evaluated in the November 1985 plan, but the costs have been refined based on a more detailed analysis.

Benefits--The project would reduce the volume of stormwater entering the combined sewer system from approximately 480 acres of residential area, thus reducing the overflows at the Montlake regulator station.

2. Install New Storm Drainage System in Madrona Basin to Harrison Street Tunnel

Description--This project (along with the Harrison Street tunnel) would complete the partial separation of the sanitary and storm drainage systems in the area draining to the Harrison Street tunnel. It would install additional storm drains, connect the existing catch basins or add new catch basins to the existing storm drain trunk mains, and discharge via the Harrison Street tunnel directly into Lake Washington, without combining with the sanitary flow.

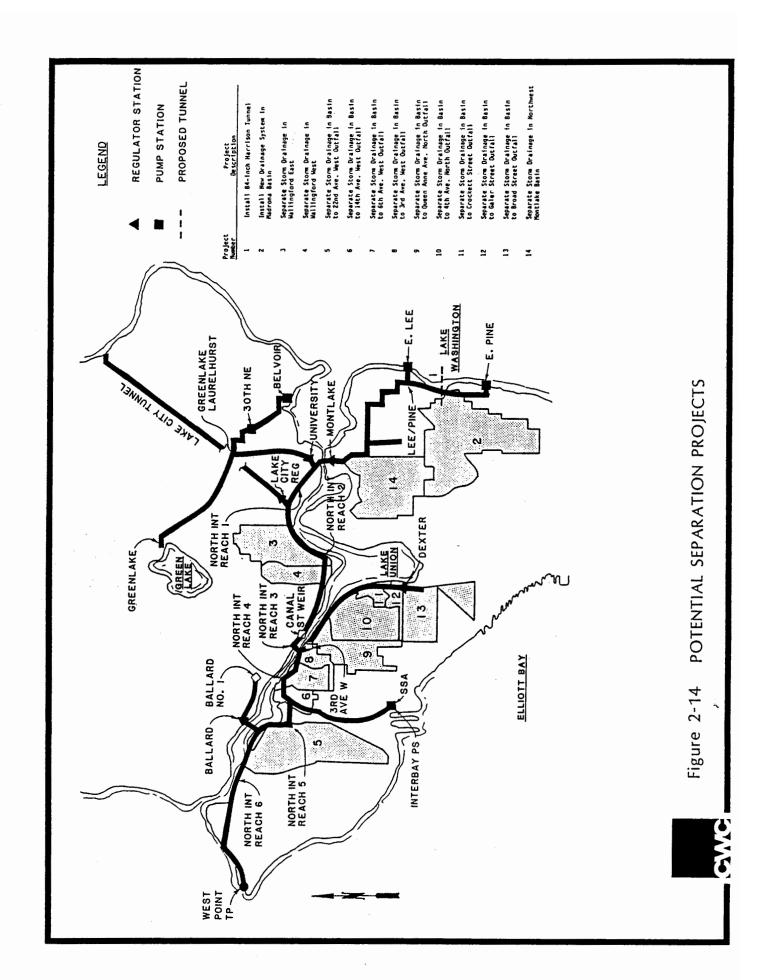
Benefits--This project would reduce the volume of stormwater entering the combined sewer system from approximately 231 acres of residential area, thus reducing overflows at the Montlake regulator station.

3. Separate Storm Drainage in Wallingford East

Description--The residential area of Wallingford East between I-5 and Meridian Avenue North connects to the NI (Reach 2) and is served by a combined sewer system that transports stormwater runoff as well as sanitary flows.

This project would partially separate the stormwater runoff from the area by installing storm drains, connecting the existing catch basins or adding new catch basins, and discharging directly into Lake Union, without combining with sanitary flow.

Benefits--The Wallingford East project would reduce stormwater from approximately 378 acres of residential and multi-family area, thus reducing overflows at the Canal Street weir.



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4. Separate Storm Drainage in Wallingford West

Description--The residential area of Wallingford West between Meridian Avenue North and Stone Avenue North and south of North 45th Street connects to the NI (Reach 2) and is served by a combined sewer system.

This project would partially separate the stormwater runoff from the area by installing storm drains, connecting the existing catch basins or adding new catch basins, and discharging directly into Lake Union, without combining with sanitary flow.

Benefits--This project would reduce the volume of stormwater entering the combined sewer system from approximately 175 acres of residential and multi-family area, thus reducing overflows at the Canal Street weir.

5. Separate Storm Drainage to 22nd Avenue West Outfall

Description--The area of Northeast Magnolia between Thorndyke Avenue West and Salmon Bay that connects to the NI (Reaches 5 and 6) is served by a combined sewer system that transports stormwater runoff as well as sanitary flows.

This project would partially separate the stormwater runoff from the area by installing storm drains, connecting the existing catch basins or adding new catch basins, and discharging directly into Salmon Bay via a 22nd Avenue West outfall, without combining with sanitary flow.

Benefits--The project would reduce stormwater entering the combined sewer system from approximately 576 acres of residential and multi-family area by two-thirds, thus reducing overflows in the vicinity of the Ballard trunk.

6. Separate Storm Drainage to 14th Avenue West Outfall

Description--The area of Northeast Queen Anne, due east of the Salmon Bay terminal, connects to the NI (Reach 4) and is served by a combined sewer system.

This project would partially separate the stormwater runoff from the area by installing storm drains, connecting the existing catch basins or adding new catch basins, and discharging directly into the Lake Washington Ship Canal via a 14th Avenue West outfall, without combining with sanitary sewage.

Benefits--This project would reduce the volume of stormwater entering the combined sewer system from approximately 69 acres of residential and multi-family area, thus reducing overflows between 3rd Avenue West and West Point.

7. Separate Storm Drainage to 6th Avenue West Outfall

Description--The area in North Queen Anne between 6th Avenue West and Jesse Avenue West that connects to the NI (Reach 4) is served by a combined sewer system.

This project would partially separate the stormwater runoff from the area by installing storm drains, connecting the existing catch basins or adding new catch basins, and discharging directly into the Lake Washington Ship Canal via a 6th Avenue West outfall, without combining with sanitary flow.

Benefits--The project would reduce stormwater entering the combined sewer system from approximately 73 acres of residential and multi-family area by about two-thirds, thus reducing overflows between 3rd Avenue West and West Point.

8. Separate Storm Drainage to 3rd Avenue West Outfall

Description--The North Queen Anne area (including Seattle Pacific University), which connects to the CI and the Metro weir at 3rd Avenue West, is served by a combined sewer system.

This project would partially separate the stormwater runoff from the area by installing storm drains, connecting the existing catch basins or adding new catch basins, and discharging directly into the Lake Washington Ship Canal via a 3rd Avenue West outfall, without combining with sanitary sewage.

Benefits--This project would reduce the volume of stormwater entering the combined sewer system from approximately 60 acres of residential and multi-family area, thus reducing overflows at the 3rd Avenue West weir.

9. Separate Storm Drainage to Queen Anne Avenue North Outfall

Description--The Queen Anne area north of Garfield Street between 1st Avenue North and 6th Avenue West that connects to the CI is served by a combined sewer system.

This project would partially separate the stormwater runoff from the area by installing storm drains, connecting the existing catch basins or adding new catch basins, and discharging directly into the Lake Washington Ship Canal via a Queen Anne Avenue North outfall, without combining with sanitary flow.

Benefits--The project would reduce stormwater entering the combined sewer system from approximately 238 acres of residential and multi-family area, thus reducing the overflows at the 3rd Avenue West weir.

10. Separate Storm Drainage to 4th Avenue North

Description--The Queen Anne area north of West Galer Street between 4th Avenue North and 1st Avenue North that connects to the CI is served by a combined sewer system.

This project would partially separate the stormwater runoff from the area by installing storm drains, connecting the existing catch basins or adding new catch basins, and discharging directly into the Lake Washington Ship Canal via a 4th Avenue North outfall, without combining with sanitary sewage.

Benefits--This project would reduce the volume of stormwater entering the combined sewer system from approximately 286 acres of residential and multi-family area by about two-thirds, thus reducing overflows at the 3rd Avenue West weir.

11. Separate Storm Drainage to Crockett Street Outfall

Description--The lakefront and hilly area southeast of the Aurora Bridge to Howe Street that connects to the CI is served by a combined sewer system.

This project would partially separate the stormwater runoff from the area by installing storm drains, connecting the existing catch basins or adding new catch basins, and discharging directly into Lake Union via a Crockett Street outfall, without combining with sanitary sewage.

Benefits--The project would reduce stormwater entering the combined sewer system from approximately 109 acres of commercial, residential and multi-family area, thus reducing the overflows at the 3rd Avenue West weir.

12. Separate Storm Drainage to Galer Street Outfall

Description--The area north of Galer Street between 4th Avenue North and Lake Union that connects to the CI is served by a combined sewer system.

This project would partially separate the stormwater runoff from the area by installing storm drains, connecting the existing catch basins or adding new catch basins, and discharging directly into Lake Union via a Galer Street outfall, without combining with sanitary flow.

Benefits--This project would reduce the volume of stormwater entering the combined sewer system from approximately 75 acres of commercial, residential and multi-family area, thus reducing overflows at the 3rd Avenue West weir.

13. Separate Storm Drainage to Broad Street Outfall

Description--The area north of the Seattle Center--between Roy Street and Galer Street in the north, and Broad Street and Denny Way in the south--connects to the CI and is served by a combined sewer system.

This project would partially separate the stormwater runoff from the area by installing storm drains, connecting the existing catch basins or adding new catch basins, and discharging directly into Lake Union via a Broad Street outfall, without combining with sanitary sewage.

Benefits--The project would reduce stormwater entering the combined sewer system from approximately 239 acres of commercial, residential and multi-family area, thus reducing overflows at the Dexter Avenue regulator station.

14. Separate Storm Drainage in Northwest Montlake Basin

Description--The residential area of Northwest Montlake and North Capitol Hill, bounded by Federal Avenue to the west, 24th Avenue East to the east, East Aloha Street to the south, and Portage Bay to the north, connects to the LWI and is served by a combined sewer system that transports stormwater runoff as well as sanitary flows.

This project would partially separate the stormwater runoff from the area by installing storm drains, connecting the existing catch basins or adding new catch basins, and discharging directly into Portage Bay and Union Bay without combining with the sanitary flow.

Benefits--The amount of stormwater entering the combined sewer system from approximately 595 acres of residential and multi-family area would be reduced by two-thirds, thus reducing the overflows at the Montlake regulator station.

Table 2-14 presents a summary of project costs, amount of impervious area reduced (prevented from discharging to combined sewers), cost per project acre, and cost per impervious acre.

Table 2-15 ranks the projects in order of increasing cost per impervious acre.

TABLE 2-14

COST SUMMARY FOR ADDITIONAL
NSA SYSTEM SEPARATION PROJECTS

Project	Project Cost. \$	Project Area, acres	Cost per Project Acre. \$	Reduction in Impervious Area, acres	Cost per Impervious Acre. \$
Harrison StMadrona Area					
1. Harrison St. Tunnel	7,820,000	480	16,300	105	74,000
2. Madrona Basin	2,150,000	231	9,300	57	38,000
Wallingford Area					
3. Wallingford East	8,020,000	378	21,200	84	95,000
4. Wallingford West	2,540,000	175	14,500	42	60,000
Oueen Anne Area					
5. 22nd Ave. W. Outfall	10,950,000	576	19,000	135	81,000
6. 14th Ave. W. Outfall	1,170,000	69	17,000	14	84,000
7. 6th Ave. W. Outfall	1,960,000	73	26,800	14	140,000
8. 3rd Ave. W. Outfall	1,270,000	60	21,200	11	115,000
9. Queen Anne Ave. Outfall	5,470,000	238	23,000	48	114,000
10. 4th Ave. N. Outfall	6,840,000	286	23,900	68	101,000
West Side Lake Union					
11. Crockett St. Outfall	1,960,000	109	18,000	30	65,000
12. Galer St. Outfall	1,170,000	75	15,600	28	42,000
13. Broad St. Outfall	5,280,000	239	22,100	107	49,000
Capitol Hill-Montlake					
14. N.W. Montlake Basin	9,780,000	595	16,400	139	70,000

TABLE 2-15

RANKING OF SUPPLEMENTAL NSA SEPARATION PROJECTS

Project	Cost per Impervious Acre, \$
Galer Street Outfall (12)	42,000
Broad Street Outfall (13)	49,000
Wallingford West (4)	60,000
Harrison Street Tunnel and Madrona Area Separation (1 & 2)	62,000
Crockett Street Outfall (11)	65,000
N.W. Montlake Basin (14)	70,000
22nd Avenue West Outfall (5) 14th Avenue West Outfall (6) Wallingford East (3)	81,000 84,000 95,000
4th Avenue North Outfall (10)	101,000
Queen Anne Avenue Outfall (9)	114,000
3rd Avenue West Outfall (8)	115,000
6th Avenue West Outfall (7)	140,000

In addition, a small separation project is being implemented by the City. The Dravus project (also known as the Queen Anne West project) is located immediately south of the 14th Avenue West project described above, roughly between Dravus Street (north), West Blaine Street (south), 15th Avenue West (west), and 7th Avenue West (east). The project area includes 245 acres served by combined sewers presently contributing to CSO through a City of Seattle outfall (Permit No. 068). Design has been completed by the City for partial separation of the area at an estimated construction cost (1986) of \$2,700,000, and the project is expected to be constructed in the near future. Because this project is being separately funded by the City, it is not shown as a Metro project. The effects of the project are included in estimates of year 2005 CSO volumes.

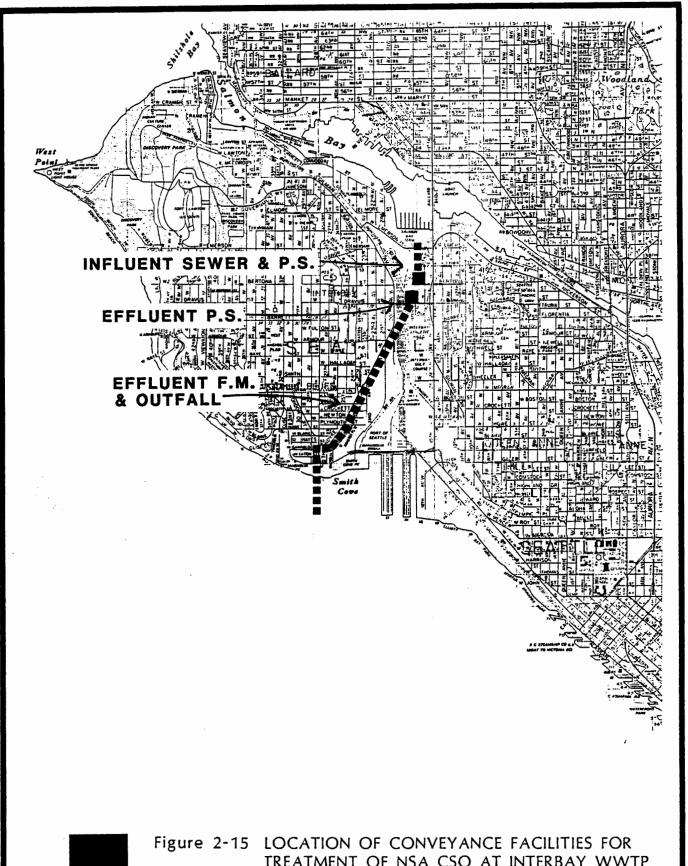
Treatment at Interbay Plants when Sewers Are Sized for Base Flows--One treatment alternative for NSA CSO involves use of the secondary treatment plant. This alternative would be used to achieve 90 percent CSO reduction when base case conveyance facilities are used throughout the Metro service area. The project involves treatment of NSA combined flows that exceed the capacity of the primary clarifiers when operated at 3,500 gpd/sq. ft. at either a large Interbay secondary treatment plant or a split Interbay/Duwamish plant.

For either option involving an Interbay secondary plant, a 1,000-foot influent pipeline would be constructed from the present junction of the North and Elliott Bay interceptors to the new Interbay plant. Influent and effluent pumping capacity would be added to the treatment plant to accommodate storm flows up to 100 mgd above sanitary flow rates, added pretreatment of flows bypassed to the TF/SG process, and an effluent force main would be installed to the southwest, generally following Thorndyke Avenue to Elliott Bay, where a 1,000-foot CSO outfall would be installed, as shown in Figure 2-15. The estimated costs are shown in Table 2-16.

For the split Interbay/Duwamish alternative, the amount of flow bypassing the smaller primary clarifiers is greater; thus, the bypass facilities are larger and more expensive. Flow splitting controls and in-plant piping would be required to accommodate the same 100 mgd used in the large Interbay alternative. The added cost of those facilities is shown in Table 2-17.

If an alternative is selected where the regional sewer system is sized for base flows, then further study is needed during predesign to optimize the method of treatment of added flow of combined sewage.

For those alternatives where the regional sewer system is increased in capacity, the incremental treatment costs are based upon the costs for added primary treatment capacity as shown in Appendix B.



TREATMENT OF NSA CSO AT INTERBAY WWTP

TABLE 2-16

COST ESTIMATE FOR TREATMENT OF NSA CSO IN A LARGE INTERBAY PLANT

CAPITAL COSTS	
72" Influent Sewer, 1,000 feet Influent Pumping Station, 92 mgd Effluent Pumping Station, 92 mgd Added Pretreatment Facilities 60" Effluent Force Main, 8,000 feet 60" Effluent Outfall, 1,000 feet Subtotal Inflation to Mid-1988 (23%) Allied Costs (59%)	\$ 810,000 4,110,000 4,110,000 4,000,000 5,400,000
ESTIMATED PROJECT COSTS	\$38,200,000
OPERATING COSTS	
Fine Screen Costs Treatment Cost, 126 MG/yr. @ \$300/MG ESTIMATED ANNUAL O&M COSTS, 1985 ESTIMATED ANNUAL O&M COSTS, 1991	\$ 20,000 38,000 58,000 82,000
PRESENT-WORTH O&M COSTS	\$ 1,700,000
EQUIPMENT REPLACEMENT	\$ 2,200,000
TOTAL PRESENT WORTH	\$42,100,000

TABLE 2-17

COST ESTIMATE FOR TREATMENT OF NSA CSO IN A SPLIT-SIZE INTERBAY PLANT

CAPITAL COSTS	
Pipeline and Pumping Costs (from Table 2-16) Additional Flow Control and In-Plant Conveyance Subtotal Inflation to Mid-1988 (23%) Allied Costs (59%)	\$19,500,000 <u>1,800,000</u> \$21,300,000 4,900,000 <u>15,500,000</u>
ESTIMATED PROJECT COSTS	\$41,700,000
OPERATING COSTS	
Labor and Miscellaneous for Additional Pretreatment ESTIMATED ANNUAL O&M COSTS, 1985 ESTIMATED ANNUAL O&M COSTS, 1991	\$ 10,000 10,000 14,000
PRESENT-WORTH O&M COSTS	\$ 290,000
EQUIPMENT REPLACEMENT	\$ 2.800,000
TOTAL PRESENT WORTH	\$44,790,000

EVALUATION OF CSO CONTROL ALTERNATIVES

Model Revisions

Following completion of the final plan for CSO control (Volume III) in November 1985, additional work has been performed to more precisely determine the locations at which overflows occur in the City of Seattle's system as well as Metro's. During this added work, additional hydrologic and hydraulic subbasin characteristic data were collected. Detailed schematics were produced for most of the SSA and a portion of the NSA. These schematics diagram the City/Metro sewer system, outfalls, and City storage projects in basins where City overflows exist. An extensive effort was made to estimate connected impervious and pervious acreage for present and future (2005) conditions, based on aerial photos, zoning maps, drainage ordinances, and projected land use and populations. These results more accurately depict the current physical system than do the data used in Metro's existing comprehensive CSO control plan, which was adopted in 1979.

Hydrologic boundaries have been rearranged from those used in previous studies in order to better define the overflows that occur at each specific location. By separating areas controlled by City regulators from those contributing directly to Metro trunks, the runoff and CSO at individual overflow points were more accurately modeled.

Detailed schematics of the combined drainage basins have been completed and reviewed by the City and Metro. SSA runoff hydrographs for the year 2005 have been revised based on the updated subbasin data. All three models (HYD 72, EBIPRE, and SSACRO) were revised to incorporate the added information. Following recalibration of the models, CSO options for secondary system alternatives 1 through 4 were tested with the revised models. The SSACRO model was also revised to incorporate the system features unique to secondary system alternative 5.

Effects of Model Revisions on Baseline CSO Volumes

As a result of the model improvements, estimates of existing CSO volumes were revised. There are not enough historic flow measurement data to fully define the existing CSO volumes by direct measurements. Existing CSO volumes were estimated by calibrating the model predictions for portions of the service area where CSO was measured and then using this calibrated model to predict CSO volume where flows were not measured or where inadequate data were available.

In the NSA, the estimated volume of CSO was revised from 366 MG/year to 468 MG/year to include the effects of runoff from unpaved, pervious area and updated information on the area connected to combined sewers in the NSA. In the SSA, the estimated volume was revised from 1,739 MG/year to 1,941 MG/year for similar reasons.

Calculation of Pollutant Loadings

One of the purposes of this supplemental analysis of CSO control alternatives is to refine the estimates of pollutant loadings associated with various CSO control alternatives. In the November 1985 CSO control plan, Table 7-6 presented estimated loadings of BOD, suspended solids, and six metals for each of the four secondary system alternatives and the associated, representative CSO alternatives. The loadings were presented on a system-wide basis. In this supplement, loadings are estimated for each of the receiving waters. In cases where sewer separation is involved, the loadings associated with the separated stormwater are also estimated.

The quality of CSO and stormwater at a given location is a function of the land use (commercial, industrial, residential) in the tributary drainage basin. The quality may vary substantially from storm to storm. The quality can also vary substantially from one area to another, even for the same land use (depending upon, for example, the amount of ongoing construction and related disturbed earth). Runoff quality from commercial and industrial areas will also vary depending upon storm characteristics and the specific types of businesses involved. Data are not available to develop estimates of runoff quality on a storm-by-storm basis or for individual drainage basins. Data collected in the Seattle area and nationally on sanitary flows, combined sewer overflows, and storm runoff were reviewed. Although data from other locations and the reviewed references provide a useful, overall perspective, greater weight was given to data collected in the Seattle area.

The quality of CSO depends upon the quality of the dry weather sewage flows and the quality of stormwater that enters the combined sewer system. The CSO loadings were estimated by determining:

- ****** The quality of sewage flows in the collection system during non-storm periods.
- ****** The quality of stormwater.
- ** The relative quantities of sewage and stormwater at the time of overflow.

The general approach was to develop typical dry weather sewage flows and stormwater characteristics by land use type. Existing basin data on land uses were used to determine the relative amount of sewage and stormwater contribution from each land use type at each Metro CSO discharge point. The existing hydraulic models were used to determine the relative quantities of dry weather and storm flows when CSO occurs. The modified model was used to compute the loading of pollutants based upon the volume of overflow and the calculated blend of storm and dry weather flow sources in each drainage basin.

The pollutant concentrations and the effects of treatment that were used to estimate pollutant loadings are shown in Table 2-18. Five pollutants were selected as examples. Selection of BOD, suspended solids, cadmium, lead and zinc was based on the availability of data from dry and wet weather flows in the Seattle area. Other pollutants are also of concern, including bacteria and viruses. Sewer separation projects will reduce CSO-related bacteria and virus discharges to a greater degree than they will reduce suspended solids and metal discharges but, unfortunately, bacteria and virus discharges are difficult to quantify. Pollutant concentration values for CSO events predicted by the model were validated by comparing them to actual concentrations measured at Metro CSO sites.

The loadings calculated by this method should be considered only to illustrate the relative locations and magnitudes of CSO-related loads for various CSO control alternatives and to put them in perspective when compared to the loadings in secondary effluent. The calculated CSO loadings should not be used for estimating any specific water quality impacts. They are approximations for comparative purposes only, and due to the limited data available, are subject to large variations.

TABLE 2-18

POLLUTANT CONCENTRATIONS AND TREATMENT EFFECTS USED IN CALCULATING POLLUTANT LOADINGS⁽¹⁾

	ž ģ	Non-Storm, in Sewer Concentrations (mg/L)	2 ع	8	Storm Runoff	_		
<u>Parameter</u>	Industrial	Commercial	Residential	Industrial	Commercial	Residential	Primary	Primary Secondary
Biochemical Oxygen Demand (BOD)	260	309	142	'n	F	7	æ	88
Total Suspended Solids (TSS)	220	122	185	45	30	20	9	8
Cadmium (Cd)	0.065	0.002	0.0014	0.004	0.003	0.0007	ž	88
Lead (Pb)	0.50	0.10	0.09	0.22	0.38	0.21	32	80
Zinc (Zn)	0.90	0.19	0.15	0.35	0.32	0.21	30	ĸ

(1) Refer to technical memorandum 4.01 for detailed information.

Development of Cost Estimates

The preceding cost estimates for each representative project were based on the following factors, which are consistent with the cost basis used in Volume III of the November 1985 facilities plan:

Initial construction year: 1988 Initial year of operation: 1991 Construction inflation: 7 percent 6 percent General inflation: Differential inflation for energy: 2 percent 10 percent Interest rate: End year of planning period: 2030 Equipment life: 20 years Present-worth factor (O&M): 20.478 Present-worth factor (energy): 28.080

CSO projects would probably be phased rather than all placed in operation in 1991; however, the Memorandum of Agreement stipulated that for comparisons of secondary system alterna-tives, CSO costs would be compared based on a common start-up date of 1991 for CSO projects. Thus, the costs in Chapters 2 through 4 of this supplemental plan are all presented based on a 1991 startup date. In Chapter 5, costs are also presented for phased construction (see Appendix C for project schedules), for use by Metro in estimating rate effects on a basis compatible with that used for secondary treatment. Also, other factors for inflation and interest rates are evaluated in Chapter 5.

The capital costs for each project were developed in 1985 construction dollars and escalated at 7 percent per year to 1988. Additional costs were added for sales tax (8 percent), contingency (30 percent), and allied costs (21 percent), to reflect total 1988 capital costs for each CSO project. Costs for easements or rights-of-way are part of the contingency allowance.

Equipment replacement and salvage values reflect total equipment capital costs from the initial construction estimates in 1985 dollars. It was assumed the equipment would be purchased in 1988 and would begin operating in 1991. With a 20-year life, the equipment would be replaced in 2011. At the end of year 2030, the equipment would have a net salvage value of zero. The total life-cycle costs for equipment replacement and salvage value therefore include present-worth value of the cost to replace the equipment in 2011.

The total present-worth cost in 1988 dollars reflects the sum of the total present-worth capital costs, the total present-worth O&M and energy costs, and the total equipment replacement costs.



CHAPTER 3

EVALUATION OF SECONDARY SYSTEM ALTERNATIVE 5 CSO CONTROL ALTERNATIVES

The purpose of CSO planning is to identify methods to reduce the CSO discharges identified in Chapter 1. In order to evaluate reduction of these discharges, it is necessary to study representative CSO projects to determine if there is a reasonable method of achieving the desired reduction. To select representative projects for use with each secondary system alternative, several criteria were considered.

EVALUATION CRITERIA

The following criteria (discussed in Chapter 6, Volume III, of the November 1985 plan) are used for evaluating representative CSO control projects:

- ****** Reduction in CSO Volume
- ******* Total Cost (Present Worth)
- W Unit Cost (Cost/Million Gallons of CSO Controlled)
- ****** Pollutant Loading Reduction
- ****** Aesthetic Improvement
- ** Potential for Cost-Sharing
- ****** Ease of Operation
- ** Near-Shore Sensitivities (Human Health)
- ****** Fish and Wildlife Resources
- Implementability (i.e., Rights-of-Way, Permits, Public Concerns)
- **W** Water Body Priorities
- ****** Coincident Benefits
- ****** Known "Hot Spot" Reduction
- ******* Compatibility with All Secondary Alternatives

Only the first four of the above criteria are quantitative; the other criteria are subjective. There is no attempt in this supplement to weight one subjective criteria relative to another. The following paragraphs discuss each of the criteria. Table 3-1 summarizes comparisons for subjective criteria. Subsequent tabulations of representative CSO control projects for each configuration of secondary system alternative 5 present information on the quantitative aspects of costs and CSO volume reduction.

Reduction in CSO Volume

Projects with the greatest potential for reducing CSO volumes include a storage project (EBI storage for the large Duwamish configuration of secondary system alternative 5), several separation projects, and enlarging the regional conveyance system capacity. The ranking of projects by this criterion generally follows the physical magnitude of the projects, e.g., storage volume, treatment capacity, separation area. For example, the smaller EBI storage facility used in the split Interbay/Duwamish configuration provides less CSO reduction than does the larger EBI storage facility used in the large Duwamish alternative.

This criterion must be applied with consideration of the project cost to determine the relative effectiveness of the representative projects. For example, construction of 500 million gallons of storage would provide nearly complete CSO elimination, but the cost of \$1,000,000,000 or

⁽¹⁾ Alternative to Kingdome/industrial separation.

Alternative to Diagonal separation. 8 6

Alternative to Denny CSO treatment - under park.

more makes such an alternative impractical. Where projects are similar in costs, the project providing the greater CSO reduction receives a higher ranking by this criterion. When various representative CSO projects are combined for a given secondary system alternative, the interaction between projects affects the volume reduction provided by each. Subsequent portions of this chapter present volume reductions for various combinations of representative CSO projects.

Total Cost

Comparison of the alternative projects shows that CATAD modifications, the Hanford and Diagonal separation projects, and use of portions of existing interceptors for storage make up the group of lowest-cost projects. CSO treatment plants, on the other hand, form the group of most-expensive projects. As in the case of CSO volume reduction, total cost must also be considered in conjunction with volume reduction. Obviously, a low-cost project that provides little CSO reduction is of little use. For projects that provide similar reductions in CSO volume, the project with the lowest total cost receives higher ranking by this criterion.

Unit Cost (Cost per Million Gallons of CSO Volume Reduction)

Unit cost represents the total cost of a project divided by the average CSO volume reduction associated with the project. A combination of representative projects that provides the greatest CSO reduction for the least total cost ranks highest by this criterion.

Pollutant Loading

Projects involving storage or added conveyance capacity that result in combined sewage receiving secondary treatment rank highest by this criterion. Separate CSO treatment facilities provide primary treatment and do not rank as high. Separation projects reduce CSO volume by preventing stormwater from entering the wastewater collection system. The separated sanitary sewage receives secondary treatment, but stormwater pollutants are discharged directly to receiving waters. Separate discharge of separated stormwater is an acceptable practice so long as water quality standards are not violated by the storm drain discharges. Chapter 5 of this supplement presents information on CSO-related pollutant loadings for each secondary system alternative.

Aesthetic Impacts

Project comparison regarding aesthetic impact is based on whether or not a project has a major adverse effect on high-visibility aesthetic concerns. Underground storage and separation projects, while useful for CSO control, do not have large aesthetic effects because there are no above-ground components. On the other hand, CSO treatment facilities at ground level will be visible and may cause an undesirable aesthetic effect.

Potential Cost-Sharing

Some CSO control projects, such as the Hanford separation project, have the potential for multi-agency funding because several agencies derive some benefit from the project. These projects have the greatest potential for cost-sharing.

Ease of Operation

Separation projects and alternatives involving increased conveyance capacities require comparatively little maintenance or operation. Primary treatment of storm flows at an Interbay or Duwamish secondary plant would require increased operation in terms of labor hours and use of power and chemicals, but not an increase in complexity of operation. Separate CSO treatment facilities, and storage facilities, require separately staffed operation for intermittently operated facilities and have the poorest ratings. Storage projects also require manual cleaning.

Near-Shore Sensitivities

Several representative projects either have a major impact on improving near-shore, human-contact water conditions (due to CSO reduction) at a single location, or are large enough to contribute to near-shore improvements in several locations. Examples of highly rated projects in this category include a Duwamish CSO treatment facility, EBI or Alaskan Way storage, a Denny Way CSO treatment facility, or an enlarged regional conveyance system. Separation projects are rated lower for this criterion because they result in discharge of stormwater in near-shore areas.

Fish and Wildlife Resources

A potential exists to benefit fish and wildlife resources rather than just near-shore areas where human-contact water use occurs. Alternatives that benefit near-shore sensitivities also benefit fish and wildlife resources. Other projects also have substantial beneficial impact, either where human-contact water uses are rare, or when a water-quality parameter, such as dissolved oxygen, is less important for human contact than for fish and wildlife.

Implementability

Examples of projects that are readily implementable include CATAD modifications (little structural work, all on existing facilities), the Hanford separation project (a City of Seattle project, scheduled for near-term construction, partly funded by Metro and the State of Washington), and EBI storage (limited to underground modifications to an existing facility). Most alternatives face at least some technical, social, or political difficulties. A few face major obstacles to implementation, including a Denny Way CSO treatment facility (under Myrtle Edwards Park) and Alaskan Way storage (major construction in an area of high-density traffic).

Water Body Priorities

Projects that reduce CSO discharges to inland waters are rated highest under this criterion, such as Green Lake/I-5 separation. Alternatives that reduce CSO primarily to saltwater bodies, or distribute reductions over both freshwater and saltwater areas, rank lower by this criterion.

Coincident Benefits

Some projects were found to provide benefits other than reduction of CSO volumes and pollutant loadings. Green Lake/I-5 separation would return water to Lake Washington and become a credit to the freshwater supply. The parallel Fort Lawton tunnel would provide increased reliability and operational flexibility for raw sewage flows to West Point. The State

Department of Transportation was planning to install detention basins for stormwater for an interchange near the Kingdome, but is now considering installing a storm drain in light of the potential future Kingdome/industrial area separation project. Other opportunities such as this may arise in the future which will require modification of the CSO projects or reprioritization to take advantage of them.

"Hot Spot" Reduction

The area off-shore of the Denny Way CSO discharge is known to have sediments with substantial concentrations of metals and other pollutants, a known "hot spot." The Denny Way CSO treatment alternatives, or an enlarged regional conveyance system, would provide a major reduction in untreated CSO discharges at Denny Way. Projects reducing CSO discharge at the University and Montlake regulators likewise would reduce CSO discharge to known "hot spot" areas.

Compatibility with All Secondary Alternatives

Some CSO control projects can be used regardless of which secondary alternative is selected. These can then be implemented independently, regardless of the speed with which secondary treatment is implemented. Examples of projects that can be implemented independently are the Hanford separation project and the Green Lake/I-5 separation project.

Method for Selecting Representative CSO Projects

The representative CSO projects described in this supplement represent "building blocks" that can be combined in different ways to produce different levels of CSO volume and pollutant loading reductions. For purposes of comparison, representative CSO projects must be identified for all secondary system alternatives that will provide the target CSO volume reductions of 75 and 90 percent.

There will be additional planning and CSO project analysis during the implementation of the selected secondary treatment and CSO control plan. The purpose of representative project selection in this supplement is to provide an equitable basis for comparison of the CSO aspects of the five secondary system alternatives, recognizing that the combination of CSO projects may be modified and optimized during predesign, including the selection of project locations and, in the cases of treatment, the treatment processes to be used.

In selecting representative projects, all identified potential CSO projects were first screened using the criteria in Table 3-1 for characteristics that made them difficult to implement, ineffective, or uneconomical. Volume III of the November plan describes several projects that were screened from further consideration on this basis. Of the added projects identified in this supplement, the Alaskan Way storage project was eliminated on the basis of cost and implementation problems. Also, the location of a Denny Way CSO treatment facility under Myrtle Edwards Park was eliminated because of implementation concerns. A location for the facility 1,000 feet east of the park is used instead in this supplement for all five secondary system alternatives.

The next step for each secondary system alternative 5 configuration was a ranking of the remaining projects based on unit costs; that is, to select the combination of projects that would achieve the greatest CSO volume reduction at the lowest cost. This ranking was evaluated to determine if any of the projects were unacceptable or illogical. For example, construction of a Duwamish CSO treatment facility might offer a low unit cost; however,

partial separation of the Michigan basin might achieve the target volume reduction at a lower total cost and would be used instead.

The projects subjected to the economic ranking were those that survived the initial feasibility screening and that met Department of Ecology (DOE) requirements as acceptable practice. Pollutant loadings were calculated for various combinations of representative projects and are discussed in Chapter 5. However, these loadings do not dictate selection of one alternative over another if both meet DOE requirements. For example, DOE has stated that primary treatment and disinfection of combined sewage, with discharge through a suitable outfall, is an acceptable practice so long as no violations of water quality standards occur. Some alternatives subject more combined sewage to secondary treatment, providing greater reductions in pollutant loading than do others. There is no basis to select them as representative projects if the lower cost alternatives meet DOE requirements and do not violate water quality standards. In the decision-making process, projects providing greater pollutant reductions might be selected, even though they exceed DOE requirements. If so, such a philosophy would be applied to all secondary system alternatives and would cause similar cost increases for all alternatives.

The specific considerations for selecting representative CSO control projects for secondary system alternative 5 configurations are discussed below.

LARGE DUWAMISH

As noted earlier, this supplement considered the alternative of providing storage rather than separating the Kingdome/industrial area and the Diagonal basin. DOE has stated that sewer separation is an acceptable practice for the foreseeable future, so long as the discharge of the separated stormwater does not violate water quality standards. There is the potential that future regulations may require that discharges from storm drains be subjected to some type of treatment, regardless of the impact on water quality standards. For this reason, storage instead of separation in these two basins was evaluated to determine the relative costs and pollutant loadings. The storage projects were found (see Chapter 2) to have a substantially higher cost, \$71,000,000 versus \$22,000,000.

The storage projects were sized to provide CSO volume reductions similar to those provided by the separation projects. However, the pollutant loadings were different because the separated stormwater would receive secondary treatment and be discharged to Central Puget Sound rather than to the Duwamish or Elliott Bay with a storage project. The differences in pollutant loadings from CSO discharges between separation and storage in the Kingdome and Diagonal areas were estimated, with the following results:

Pollutant Loadings (lbs/year) from CSO <u>Discharges to Receiving Water</u>

With No Controls	<u>Duwamish</u>	Elliott Bay
BOD	499,000	467,000
SS	854,000	519,000
Cđ	47	57
Pb	3,500	1,930
Zn	3,680	2,230

Pollutant Loadings from CSO and Separated Stormwater with 75% Volume Reduction--with Kingdome and Diagonal Separation

	Duy	<u>vamish</u>	Elliott	Bay
	Secondary Alternatives 1-2	Secondary Alternatives 3-4	Secondary Alternatives 1-2	Secondary Alternatives 3-4
BOD	113,700	249,200	101,300	165,800
SS	304,900	532,000	274,300	300,100
Cd	10	26	20	30
Pb	1,710	2,770	2,070	2,220
Zn	1,860	2,990	2,150	2,405

Pollutant Loadings from CSO with 75% Volume Reduction-with Kingdome and Diagonal Storage

	Duv	vamish	Elliott	Bay
	Secondary Alternatives 1-2	Secondary Alternatives 3-4	Secondary Alternatives 1-2	Secondary Alternatives 3-4
BOD	106,100	241,600	61,300	125,800
SS	217,800	450,500	103,000	129,100
Cd	7	23	7	17
Pb	1,380	2,440	590	740
Zn	1,340	2,470	585	820

Use of storage projects at Diagonal Avenue and the Kingdome would improve the removal of CSO-related pollutants discharged to the Duwamish and to Elliott Bay. However, there are many other non-point sources of these same pollutants to both the Duwamish and Elliott Bay; therefore, the total reduction in all pollutant loadings to these receiving waters would be of questionable significance. For example, a mass balance for pollutants in the Duwamish River, prepared as part of the Duwamish Clean Water Plan, found that known and/or permitted sources could account for only 1 to 5 percent of the total loads to the river and that CSOs were "minor sources of all pollutants determined except fecal coliforms." Metro's TPPS report found CSO input to be a "tiny fraction of the estimated input to the Bay from the Duwamish River." Small differences between secondary system alternatives in pounds per year of pollutants discharged become insignificant as fractions of a percent of inputs to the Duwamish or Elliott Bay. Although CSO loadings may be a small percentage of the total loadings to the Duwamish or Elliott Bay, the localized near-shore effects must be considered. In this regard, the reader should note that in alternative 4, a portion of the load to Elliott Bay will be discharged through an extended outfall from the Denny Way CSO facility and near-shore discharges at Denny Way will be essentially eliminated.

The Diagonal and Kingdome/industrial area separation projects are used as representative projects in all secondary system alternative 5 configurations (as well as retained in secondary system alternatives 1 through 4) because:

- ******* They are lower in cost.
- **They avoid operational costs and problems inherent in storage.**

- ******* They avoid potential odors associated with storage.
- They do not use land that could be put to other urban use.
- Present and foreseeable standards do not require treatment of stormwater, so long as water quality standards are met. There are no data to indicate that storm drain discharges would cause violation of water quality standards.
- The incremental pollutant removal from these two storage projects has no demonstrable benefit to water quality.

During implementation of the plan, the storage projects can be further evaluated. If used, they would affect the cost of all secondary system alternatives in a similar manner; thus, such a later decision would not alter the relative economics of one secondary alternative versus another.

As described in Chapter 2, secondary system alternative 5 involves the construction of new regional sewer and treatment facilities. The size of these new facilities could be increased to transport and treat more combined sewage flows. Alternative sizes of these new facilities were considered to transport the flows associated with various design storms as follows:

<u>Transport</u>	System Capacity
Base Flows	371 mgd
Storm 2	457 mgd
Storm 4	682 mgd
Storm 6	989 mgd

Using the approach described earlier, representative CSO control projects were identified for each regional system capacity, as shown in Table 3-2. Sizing the regional system for flows associated with storm 2 resulted in the lowest-cost approach for the comparative targets of both 75 and 90 percent CSO volume reduction. It should be noted from Table 3-2 that sizing the regional system for storm 4 flows would enable the 90 percent volume reduction to be approached without the use of sewer separation projects in the SSA. This would avoid the potential for future costs if regulations governing storm drain discharges should change. Adoption of this approach would add about \$46,000,000 to the CSO control costs. Since DOE has stated that sewer separation is an acceptable practice for the foreseeable future, storm 2 flows are used as the basis for the regional system capacity. Also, as can be noted from Table 3-2, sizing the regional sewers for the larger flows associated with Storm 4 would enable reductions greater than 95 percent to be achieved with only one separation project. To accomplish similar removals with sewers sized for storm 2, it would be necessary to add further primary capacity at Duwamish as well as added conveyance system capacity to get more flow to the Duwamish site. Representative projects selected for comparative purposes for the large Duwamish configuration are shown in Table 3-3.

Table 3-3 is based upon achieving the target goals of 75 and 90 percent CSO reduction in both the SSA and the NSA, as specified in the Memorandum of Agreement. It is evident that increasing the level of CSO reduction is more costly per gallon in the NSA. If the target goals were revised to be an overall reduction of 75 and 90 percent, the costs for CSO control would be reduced (as illustrated in Table 3-4) at the 75 percent target. However, at the 90 percent target, there is little difference in cost because it also becomes costly in the SSA to remove added CSO volumes as the target increases from 75 to 90 percent. The remainder of this supplement addresses alternatives on the basis of equal CSO reductions in both the NSA and the SSA; however, if reduction calculated on an overall basis proves acceptable to DOE, there will be savings in costs at the 75 percent target.

TABLE 3-2
COST/VOLUME EFFECT RELATIONSHIP OF REPRESENTATIVE CSO CONTROL PROJECTS FOR LARGE DUWAMISH CONFIGURATION

	Annual	Cumulative	Cost	
22.	Vol. CSO	Percent	(millions, 19	
<u>SSA</u> F	cemaining(MG	Reduction ⁽¹⁾	<u>Incremental</u>	Cumulative
Existing CSO Volume Sewers Sized for:	1,941			
Base Flows (Year 2005)			10.2	10.2
Hanford, CATAD & EBI Storage ^{(S}		51	15.4	25.6
Plus Diagonal Separation	753	61	2.9	28.5
Plus Kingdome/Industrial Separat		70	18.9	47.4
Plus Michigan Separation	410	79	24.3	71.7
Plus Duwamish CSO Plant	194	90	53.6	125.3
Storm 2			39.7	39.7 ⁽²⁾
Hanford, CATAD & EBI Storage	3) 715	63	16.8	56.5
Plus Diagonal Separation	529	72	2.9	59.4
Plus Kingdome/Industrial Separat	ion 395	80	18.9	78.3
Plus Michigan Separation	192	91	24.3	102.6
Storm 4			126.2	126.2(2)
Hanford, CATAD & EBI Storage	3) 218	89	19.8	146.0
Plus Diagonal Separation	40	98	2.9	148.9
Storm 6			236.8	236.8 ⁽⁴⁾
Hanford, CATAD & EBI Storage(S	94	95	20.6	257.4
NSA			·	
Existing CSO Volume Sewers Sized for:	468			
Base Flows (Year 2005)				
CATAD	550		2.8	2.8
Plus Green Lake/I-5 Separation	421	10	10.2	13.0
Plus Separation Projects ⁽⁵⁾	245	48	42.0	55.0
Plus Fort Lawton Tunnel Storage	150	68	7.6	62.6
Plus University Storage	89	81	28.2	90.8
Plus Added Sep. & Storage Proj. (6)	47	90	33.2	124.0
Storms 2, 4, 6				
CATAD ⁽³⁾	356	24	3.9	3.9
Plus Green Lake/I-5 Separation ⁽⁵⁾	237	49	10.2	14.1
Plus Separation Projects	122	74	42.0	56.1
Plus Fort Lawton Tunnel Storage	101	78	7.6	63.7
Plus University Storage	37	92	28.2	91.9

TABLE 3-2 (Continued)

- (1) Based on existing CSO volumes.
- (2) Costs to increase regional system capacity to accommodate flows associated with design storms; see Appendix B.
- (3) Including added secondary treatment costs.
- (4) Including \$10,500,000 for West Duwamish sewers.
- (5) Projects 1 5 and and 11 14 from Table 2-15.
- (6) Storage at Ballard regulator and Ballard No. 1 weir, plus remaining four separation projects from Table 2-15.

TABLE 3-3
REPRESENTATIVE CSO PROJECTS USED FOR LARGE DUWAMISH

	Cost (n	0016	
	Present	Comital	O&M
75 PERCENT REDUCTION	<u>Worth</u>	<u>Capital</u>	(\$1,000/yr)*
73 FERCENT REDUCTION			
Added Secondary PlanTO&M	\$ 1.4		\$ 68.0
Alki and Carkeek CSO Plants	22.2	\$12.6	330.0
Hanford Separation	3.0	3.0	
CATAD Modifications	5.6	5.6	
EBI Storage	17.8	10.8	240.0
Diagonal Separation	2.9	2.9	
Kingdome/Industrial Area Separation	6.2	6.2	
Green Lake/I-5 Separation	10.2	10.2	2.0
NSA Separation Projects	36.2	36.2	
Ft. Lawton Storage Project	7.6	6.2	50.0
Subtotal	\$113.1	\$ 93.7	\$690.0
Regional System Cost for Storm 2 Flows	<u>39.7</u>	<u>39.7</u>	
TOTAL	\$152.8	\$133.4	\$690.0
ADDED PROJECTS FOR 90 PERCENT RED	UCTION		
Projects for 75% Volume Reduction	\$152.8	\$133.4	\$690.0
Kingdome/Industrial Area Separation (balance	e) 12.7	12.7	
Michigan Separation	24.3	24.3	
NSA Separation Projects	2.5	2.5	
University Storage	28.2	<u>27.6</u>	20.0
TOTAL	\$220.5	\$200.5	\$710.0

TABLE 3-4

RELATIVE COSTS TO ACHIEVE TARGET CSO REDUCTIONS IN BOTH NSA AND SSA VERSUS AN OVERALL BASIS FOR CSO VOLUME REDUCTIONS FOR LARGE DUWAMISH

Total Existing CSO = 1,941 + 468 = 2,409 MG/Year

75 Percent Reduction = 601 MG/Year Remaining

90 Percent Reduction = 240 MG/Year Remaining

		Cost (million \$)		
		Using Overall	Using Same Target	
		Basis for	Reduction in Both	
Using Overall Basis:	MG/year	Reduction	SSA & NSA	
Comp Cyclan David.	<u> </u>	11000011011	5511 55 11511	
Alki and Carkeek		22.2		
SSA (see Table 3-2)		22.2		
Storm 2 Projects,				
Kingdome + 15% of Mich. Sep.	364	79.3		
NSA, Storm 2	304	77.5		
Projects Through Green Lake	237	_14.1		
Trojects Through Green Bake	<u>251</u>			
75% Target Reduction Totals	601 ⁽¹⁾	115.6	152.8(2)	
7570 Targot Madadion Totals	001	110.0	132.0	
For 90% Target Reduction:				
Alki and Carkeek		22.2		
SSA, Storm 2 Projects (Table 3-2)		99.9		
+ 50 mgd Duwamish CSO Plant	118	56.0		
NSA, Storm 2 Projects,				
Through Separation Projects	122	<u>56.1</u>		
	4-1			
90% Target Reduction Totals	240 ⁽³⁾	234.2	220.5 ⁽²⁾	

^{(1) 75%} overall reduction as a result of 81% in SSA and 49% in NSA.

⁽²⁾ From Table 3-3.

^{(3) 90%} overall reduction as a result of 94% in SSA and 74% in NSA.

LARGE INTERBAY

The cost/volume effects for representative CSO projects for the large Interbay configuration are shown in Table 3-5 for each of the capacities of the regional system considered. The approach and rationale have been described in the preceding pages and are not repeated here. It was found that sizing the regional system for storm 2 flows provided the lowest-cost approach for both 75 and 90 percent reduction. It should be noted from Table 3-5 that at 90 percent volume reduction, increasing the capacity of the regional system to convey storm 4 flows is competitive in cost with the storm 2 sizing. Using the storm 4 capacity has the advantage of eliminating several projects, including three separation projects. Using the storm 4 flows has the disadvantage of not being amenable to phasing. If the large Interbay configuration is selected, the optimization of the size of the regional conveyance and treatment system should receive further study. The storm 2 conveyance capacity is used as the basis for representative projects because of its compatibility with project phasing, which may be necessary to match Metro's fiscal resources. Because separation alone would not achieve 75 percent reduction in the NSA, the University storage project was used in conjunction with separation of a part of the identified separation projects in the NSA. The remaining separation projects were used to achieve 90 percent. Table 3-6 shows the representative CSO projects used for the large Interbay option.

SPLIT INTERBAY/DUWAMISH

Table 3-7 shows the cost/volume effects for representative CSO projects selected for the split Interbay/Duwamish configuration. Again, sizing the regional system for storm 2 flows provided the lowest-cost approach for both 75 and 90 percent reduction. Table 3-8 shows the representative projects used for the split plants.

The split Interbay/Duwamish option reverses the flows from King Street south to the Duwamish site. The Pike Street adit north would be conveyed to an Interbay plant. The secondary planning team proposes to convey sewage from King Street south with 36- to 66-inch sewers. It would be necessary to increase the size of these pipes to 60 to 90 inches, at an increased cost of \$15,000,000, to optimize the potential CSO benefits associated with this configuration.

The flows being carried northerly by the Interbay pumping station are based on the secondary planning assumption of 28 mgd. Under this assumption, treatment of the Denny CSO would be required to achieve 90 percent volume reduction. The split-size Interbay plant would have space for potential use for treatment of the Denny Way CSO. Representative project costs are based on the same location for the Denny Way facility used in the other alternatives. If the split Interbay/Duwamish option is selected, consideration should be given to locating the Denny CSO treatment facility at the Interbay plant site and using the existing Interbay pumping station to convey the combined sewage to that site. Also, as discussed for the large Interbay alternative, sizing of the regional conveyance system for storm 4 flows should receive further consideration if the split Interbay/Duwamish option is selected.

TABLE 3-5

COST/VOLUME EFFECT RELATIONSHIP OF REPRESENTATIVE CSO CONTROL PROJECTS FOR LARGE INTERBAY CONFIGURATION

SSA	Annual Vol. CSO Remaining (MG)	Cumulative Percent Reduction ⁽¹⁾	Cos (millions, 198 Incremental	
Existing CSO Volume Sewers Sized for:	1,941			
Base Flows (Year 2005)				
Hanford, CATAD	1,396	28	5.8	5.8
Plus Diagonal Separation	1,234	36	2.9	8.7
Plus Kingdome/Industrial Separation	928	52	18.9	27.6
Plus Michigan Separation	689	65	24.3	51.9
Plus Denny CSO Plant	456	77	52.2	104.1
Plus Duwamish CSO Plant	195	90	93.7	197.8
Storm 2			33.4	33.4(2)
Hanford, CATAD ⁽³⁾	1,048	46	7.9	41.3
Plus Diagonal Separation	845	56	2.9	44.2
Plus Kingdome/Industrial Separation		69	18.9	63.1
Plus Michigan Separation	396	80	24.3	87.4
Plus Denny CSO Plant	206	90	52.2	139.6
Plus Duwamish CSO Plant	104	95	93.7	233.3
Storm 4		,	133.7	133.7(2)
Hanford, CATAD ⁽³⁾	190	90	13.2	146.9
Storm 6			274.6	274.6 ⁽⁴⁾
Hanford, CATAD ⁽³⁾	100	95	13.8	288.4
NSA				
Existing CSO Volume Sewers Sized for:	468			
Base Flows (Year 2005)				
CATAD	550		2.8	2.8
Plus Green Lake/I-5 Separation	421	10	10.2	13.0
Plus Separation Projects(5)	245	48	42.0	55.0
Plus Use Interbay Plant ⁽⁶⁾	108	77	42.1	97.1
Plus University Storage	47	90	28.2	125.3

TABLE 3-5 (Continued)

	Annual Vol. CSO Remaining (MG)	Cumulative Percent Reduction ⁽¹⁾	Cos (millions, 198 Incremental	
Storms 2. 4. 6 CATAD(3) Plus Green Lake/I-5 Separation Plus Separation Projects Plus University Storage Plus Added Separation Projects	356	24	3.9	3.9
	237	49	10.2	14.1
	122	74	42.0	56.1
	58	88	28.2	84.3
	47	90	15.5	99.8

⁽¹⁾ Based on existing CSO volumes.

⁽²⁾ Costs to increase regional system capacity to accommodate flows associated with design storms; see Appendix B.

⁽³⁾ Including additional treatment costs.

⁽⁴⁾ Including \$10,500,000 for West Duwamish sewers.

⁽⁵⁾ Projects 1 - 5 and and 11 - 14 from Table 2-15.

⁽⁶⁾ See Table 2-16.

TABLE 3-6
REPRESENTATIVE CSO PROJECTS USED FOR LARGE INTERBAY

	Cost (millions)			
	Present		O&M	
	Worth	Capital	(\$1,000/yr)*	
75 PERCENT REDUCTION	<u></u>		XX = 1 X X X X X X X X X X X X X X X X X	
Added Secondary Plant O&M	\$ 2.1		\$104.0	
Alki and Carkeek CSO Plants	22.2	\$ 12.6	330.0	
Hanford Separation	3.0	3.0		
CATAD Modifications	5.6	5.6		
Diagonal Separation	2.9	2.9		
Kingdome/Industrial Area Separation	18.9	18.9		
Michigan Separation	10.9	10.9		
Green Lake/I-5 Separation	10.2	10.2	2.0	
NSA Separation Projects	20.5	20.5		
University Storage	28.2	<u>27.6</u>	20.0	
Subtotal	\$124.5	\$112.2	\$456.0	
Conveyance Cost	33.4	<u>33.4</u>		
TOTAL	\$157.9	\$145.6	\$456.0	
90 PERCENT REDUCTION				
Projects for 75% CSO Volume Reduction	\$157.9	\$145.6	\$456.0	
Denny CSO Treatment	52.2	49.8	83.0	
Michigan Separation (Balance)	13.4	5.4		
NSA Separation Projects	<u>37.0</u>	<u>37.0</u>		
TOTAL	\$260.5	\$237.8	\$ 539.0	

^{* 1985} annual O&M.

TABLE 3-7

COST/VOLUME EFFECT RELATIONSHIP OF REPRESENTATIVE CSO CONTROL PROJECTS FOR SPLIT INTERBAY/DUWAMISH CONFIGURATION

	Annual	Cumulative	Cost	
	Vol. CSO	Percent	(millions, 1	
<u>SSA</u>	Remaining (MG)		Incremental	Cumulati
		217000011011	THO COMPANIA	Comunati
Existing CSO Volume	1,941			
Sewers Sized for:	·			
Base Flows (Year 2005)				
Hanford, CATAD & EBI Storage	1,239	36	15.4	15.4
Plus Diagonal Separation	1,023	47	2.9	18.3
Plus Kingdome/Industrial Separation		58	18.9	37.2
Plus Michigan Separation	562	71	24.3	61.5
Plus Denny CSO Plant	100	95	52.2	113.7
Plus Duwamish CSO Plant	71	96	89.7	203.4
Charles and the state of the st			22.0	22.2(2)
Storm 2			23.8	23.8 ⁽²⁾
Hanford, CATAD & EBI Storage ⁽³⁾	882	55	17.6	41.4
Plus Diagonal Separation	681	65	2.9	44.3
Plus Kingdome/Industrial Separation		72	18.9	63.2
Plus Michigan Separation	367	81	24.3	87.5
Plus Denny CSO Plant	100	95	52.2	139.7
Storm 4			121.0	121.0(2)
Hanford, CATAD & EBI Storage(3)	324	83	21.0	142.0
Plus Diagonal Separation	146	92	2.9	144.9
_				4.5
Storm 6			253.4	253.4 ⁽⁴⁾
Hanford, CATAD & EBI Storage ⁽³⁾	191	90	12.2	265.6
<u>NSA</u>				
Existing CSO Volume	468			
Sewers Sized for:			•	•
Base Flows (Year 2005)				
CATAD	550	••	2.8	2.8
Plus Green Lake/I-5 Separation	421	10	10.2	13.0
Plus Separation Projects ⁽⁵⁾	245	48	42.0	55.0
Plus Use Interbay Plant ⁽⁶⁾	108	46 77	42.0 44.8	99.8
Plus University Storage	47	90	28.2	128.0
itus Oniversity Storage	7/	<i>,</i> 0	20.2	120.0

TABLE 3-7 (Continued)

	Annual Vol. CSO Remaining (MG)	Cumulative Percent Reduction ⁽¹⁾	Co. (millions, <u>Incremental</u>	st 1988 dollars) <u>Cumulative</u>
Storms 2, 4, 6				
CATAD(3)	356	24	3.9	3.9
Plus Green Lake/I-5 Separation	237	49	10.2	14.1
Plus Separation Projects	122	74	42.0	56.1
Plus University Storage	58	88	28.2	84.3
Plus Added Separation Projects	47	90	15.5	99.8

⁽¹⁾ Based on a year with average rainfall; existing CSO with no CSO controls = 1,941 MG/year in SSA and 466 MG/year in NSA.

⁽²⁾ Costs to increase regional system capacity to accommodate flows associated with design storms; see Appendix B.

⁽³⁾ Including added secondary treatment costs.

⁽⁴⁾ Including \$10,500,000 for West Duwamish sewers.

⁽⁵⁾ Projects 1 - 5 and 11 - 14 from Table 2-15.

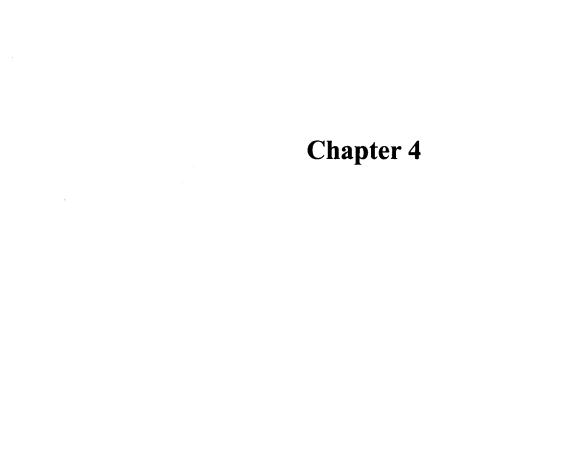
⁽⁶⁾ See Table 2-17.

TABLE 3-8

REPRESENTATIVE CSO PROJECTS USED FOR SPLIT INTERBAY/DUWAMISH

			
	Present Worth	Cost (millions) Capital	O&M (\$1,000/yr)*
	WOITH	Capital	(\$1,000/YI)*
75 PERCENT REDUCTION			
Added Secondary Plant O&M	\$ 2.2		\$107.0
Alki and Carkeek CSO Plants	22.2	\$12.6	330.0
Hanford Separation		3.0	3.0
CATAD Modifications		5.6	5.6
EBI Storage	9.6	0.6	240.0
Diagonal Separation		2.9	2.9
Kingdome/Industrial Separation		18.9	18.9
Michigan Separation		8.0	8.0
Green Lake/I-5 Separation	10.2	10.2	2.0
NSA Separation Projects	20.5	20.5	
University Storage	28.2	27.6	20.0
Added Conveyance from King Street	<u>15.0</u>	<u> 15.0</u>	
Subtotal	\$146.3	\$124.9	\$699.0
Conveyance Cost	<u>23.8</u>	23.8	
TOTAL	\$170.1	\$148.7	\$699.0
90 PERCENT REDUCTION			
Projects for 75% CSO Volume Reduction	\$170.1	\$148.7	\$ 699.0
Michigan Separation	16.3	16.3	••
Denny CSO Plant (75 mgd)	41.7	40.0	60.0
NSA Separation Projects	37.0	<u>37.0</u>	
TOTAL	\$265.1	\$242.0	\$759.0

^{*1985} annual O&M.



CHAPTER 4

CSO ALTERNATIVES FOR SECONDARY SYSTEM ALTERNATIVES 1 THROUGH 4

PURPOSE OF EVALUATION

Volume III of the November 1985 facilities plan identified representative CSO control projects for each of the four secondary system alternatives. The projects were not selected to achieve the target goals of 75 and 90 percent CSO volume reduction being used for comparisons in this supplement. In Volume III, the representative projects were selected based on the "knee-of-the-curve" concept; that is, representative projects were combined until the cost-benefit curve showed a sharp increase indicating that the benefits were no longer proportional to the added costs. As a result, the combinations of representative projects achieve similar, but not identical, volume reductions for each of the four secondary system alternatives. Also, Volume III did not identify representative projects that could achieve 90 percent CSO volume reduction in the NSA. The CSO control alternatives described in Volume III were evaluated further in preparation of this supplement to:

- Identify representative CSO projects to achieve the target goals of 75 and 90 percent CSO reduction established for this supplement.
- Identify CSO projects that could be added to those in Volume III to achieve 90 percent CSO reduction in the NSA.
- Apply the refined computer models used to evaluate CSO alternatives for secondary system alternative 5 so that all alternative secondary systems are compared equitably.
- Apply the newly developed pollutant loading model to secondary system alternatives 1 through 4.

CSO CONTROL ALTERNATIVES

The representative projects, described in detail in Volume III and briefly described in Chapter 2 of this supplement, used in conjunction with secondary system alternatives 1 through 4 in the November plan include:

- ****** CATAD Improvements
- ****** Hanford Separation
- **XX** Diagonal Separation
- ****** Kingdome/Industrial Area Separation
- ****** CSO Treatment Plant Near Denny Way
- **XX** CSO Treatment Plant Near Duwamish Pumping Station
- W University Regulator CSO Control (Green Lake/I-5 Separation)
- ****** Parallel Fort Lawton Tunnel
- **Michigan Street Separation**

In addition, the following added projects described in Chapter 2 of this supplement were evaluated for secondary system alternatives 1 through 4:

- **XX** Diagonal Storage
- **XX** Kingdome Storage
- **MINIOR NSA Sewer Separation Projects Involving 2,470 Acres**
- **XX** Alaskan Way Storage

Because of costs and other considerations previously discussed in Chapter 3, the storage projects at Kingdome, Diagonal Avenue, and Alaskan Way were not used as representative projects. The separation projects for the Kingdome/industrial area and for the Diagonal basin are acceptable CSO reduction practices that accomplish similar CSO volume reductions at lower cost.

The concept of parallel operation of the primary and secondary treatment units described in Chapter 2 was also considered for system alternatives 1 through 4. Parallel operation was not found to offer any savings for these system alternatives.

Work subsequent to the November 1985 plan found that partial separation of the Lake Union area would enable a reduction in the size of a Denny Way CSO treatment facility from 100 mgd to about 75 mgd. Partial separation of the Lake Union area was estimated to cost \$20,600,000. A reduction in the Denny Way CSO treatment facility from 100 to 75 mgd would provide a savings of about \$10,000,000. However, the Lake Union separation would also reduce City CSO into Lake Union. Although Denny Way CSO treatment is used as the representative CSO project, the merits of Lake Union partial separation with a smaller Denny Way CSO facility should receive added consideration in predesign.

EVALUATION METHODOLOGY

Revision of drainage basin and collection system characterization data and revision of the predictive computer models were described in Chapter 2 of this supplement. These revised models were used to evaluate the CSO control projects listed above. The results (volume remaining, percent reduction, cost) are summarized in Table 4-1. Secondary system alternatives 3 and 4 incorporate the 133 mgd pumping rate at the Interbay pumping station used in the supplement to the secondary facilities plan for secondary system alternatives 3 and 4. Pollutant loadings for each receiving water were calculated and are discussed in Chapter 5.

The Diagonal drainage basin has CSO discharges from both Metro and the City. These CSO discharges are mixed, and both discharge from a storm drain near the Duwamish pumping station. The CSO volumes shown in this report (as in Volume III of the November 1985 plan) include the discharge from this storm drain in the CSO volumes at the Duwamish pumping station.

Based upon the results shown in Table 4-1, the representative CSO control projects shown in Tables 4-2 and 4-3 were used for secondary system alternatives 1 through 4.

Where the comparative target reductions (75 or 90) fell between two calculated points, the cost was determined by interpolation between the two points, based upon the projects involved. The costs included in Table 7-2 of Volume III for SSA CSO control were (including Alki and Carkeek): secondary system alternatives 1 and 2--\$57,900,000; secondary system alternatives 3 and 4--\$98,800,000.

The costs for 75 percent CSO reduction for secondary system alternatives 1 and 2 for the SSA and Alki and Carkeek are slightly higher (\$58,400,000 vs. \$57,900,000) than the project costs estimated in Volume III because:

TABLE 4-1

SUMMARY OF CSO PROJECT EFFECTS
FOR SECONDARY SYSTEM ALTERNATIVES 1 THROUGH 4

SSA Alternatives 1 and 2	Jobal 2409m6— Annual CSO Volume Remaining (MG)	Cumulative Percent ⁽¹⁾ Reduction	Cumulative Cost (millions, 1988 dollars)
Existing CSO Volume	1,941		
CATAD Modifications	1,541		
Plus Hanford Separation	(371) 1,570	19	5.8 ⁽²⁾
Plus Duwamish Secondary	(44) 906	53	12.0
Plus Diagonal Separation	(153) 753	61	14.9
Plus Kingdome/Ind. Sep. (3) Plus 100 mgd Denny CSO Treatmen	nt ⁽⁴⁾ (249) 504	74 85	33.8 86.0
Plus Michigan Separation ⁽⁵⁾	100	93	110.3
1145 Maniban Soparation	(157) 138	,,,	110.5
Alternatives 3 and 4			
Existing CSO Volume	1,941		
CATAD Modifications	/ > 1.20(6)	20	50
 Plus Hanford Separation Plus Diagonal Separation 	(545) 1,396. ⁽⁶⁾ (162) 1,234 (304) 930 (241) 689	28 36	5.8
Plus Kingdome/Ind. Sep.	(762) 1,234	52	(z.9) 8.7 (/ɛ.9) 27.6
Plus Michigan Separation (7)	(304) 689	65	(24.3) 51.9
Plus Denny CSO Treatment	·/225) 430	77	(52,2) 104.1
Plus 100 mgd Duwamish CSO Trea	tmont(8) 195	90	(90.0) 194.1
NSA			
Alternatives 1 and 2			
Existing CSO Volume	468		
CATAD Modifications	356	24	2.8
Plus Green Lake/I-5 Separation	236	50	13.0
Plus Parallel Fort Lawton Tunnel	168	64	30.0
Plus Nine Separation Projects ⁽⁹⁾	96 22	80	72.0
Plus University Storage	33	93	100.2
Alternatives 3 and 4			
Existing CSO Volume	468	16	2.0
CATAD Modifications	(73) 395. ⁽⁶⁾	16 42	2.8
 Plus Green Lake/I-5 Separation Plus Parallel Fort Lawton Tunnel 	(124) $\frac{211}{170}$	42 64	30.0
Plus Nine Separation Projects ⁽¹⁰⁾	(101) 170	79	72.0
Plus University Storage	7/42 36	92	100.2
	(60)		

- (1) Existing CSO Volume = 1,941 MG/year in SSA and 468 MG/year in NSA; expressed in terms of existing CSO volume in a year in which average rainfall occurs.
- (2) \$2,800,000 SSA CATAD modification and \$3,000,000 Metro share of Hanford separation (\$11,000,000 total).
- (3) For 75% volume reduction, about 10% of the Michigan separation would be included.
- (4) Based on location of 1,000 feet east of Denny Way regulator station, east of railroad tracks to the east of Myrtle Edwards Park, including 1,000 feet of outfall into Elliott Bay.
- (5) For 90% volume reduction, about 67% of the Michigan basin would be separated.
- (6) Includes effects of increasing Interbay pumping station rate from 100 mgd to 133 mgd.
- (7) For 75% volume reduction, about 90% of the Michigan basin would be separated in conjunction with Denny Way CSO Treatment Facility.
- (8) Includes cost of 1,000 feet of treated-CSO outfall and 11,500 feet of on-shore transmission line, as well as the cost of 5,000 feet of 96-inch influent sewer from Hanford and a new 100 mgd pumping station.
- (9) For 75% volume reduction, 450 impervious acres would be separated at a cost of \$29,800,000.
 For 90% volume reduction, 515 impervious acres would be separated at a cost of \$32,800,000, plus University storage.
- (10) For 75% volume reduction, 480 impervious acres would be separated at a cost of \$31,500,000.

 For 90% volume reduction, 535 impervious acres would be separated at a cost of \$35,000,000, plus University storage.

TABLE 4-2

REPRESENTATIVE CSO PROJECTS FOR
SECONDARY SYSTEM ALTERNATIVES 1 AND 2

75 PERCENT VOLUME REDUCTION	Present	Cost (millions)	
·	Worth	Capital	O&M (1,000/yr) ⁽¹⁾
Alki CSO Treatment Plant	\$ 17.9	\$10.8	\$244
CATAD Modifications	5.6	5.6	
Carkeek Park CSO Treatment Plant	4.3	1.8	86
Parallel Fort Lawton Tunnel	17.0	17.0	
Hanford Separation	3.0	3.0	
Green Lake/I-5 Separation	10.2	10.2	2
Diagonal Separation	2.9	2.9	
Kingdome/Industrial Area Separation	18.9	18.9	
Added Secondary Plant O&M ⁽²⁾	6.2		213
Michigan Separation ⁽³⁾	2.4	2.4	
NSA Separation Projects	<u>29.8</u>	<u>29.8</u>	
TOTAL	\$118.2	\$102.4	\$545
90 PERCENT VOLUME REDUCTION			
Projects for 75 Percent Volume Reduction	\$118.2	\$102.4	\$543
Added NSA Separation Projects	4.0	4.0	••
Increase Separation of Michigan Basin to 67%	13.2	13.2	
CSO Treatment near Denny Way Regulator	52.2	49.8	83
University Storage	28.2	<u>27.6</u>	_20
TOTAL	\$215.8	\$197.0	\$646

^{(1) 1985} annual O&M.

⁽²⁾ Added operation and maintenance costs experienced at secondary treatment plants for treatment of added combined sewage flows transported to the plants as a result of CSO control projects.

⁽³⁾ About 10 percent of area separated.

TABLE 4-3

REPRESENTATIVE CSO PROJECTS
FOR SECONDARY SYSTEM ALTERNATIVES 3 AND 4

		unphased	
•		Cost (millions)	
75 PERCENT VOLUME REDUCTION	Present		O&M
	Worth	<u>Capital</u>	(\$1.000/yr
CSO Equalization at Alki Treatment Plant	\$ 19.2	-\$18.5	\$ 26
CATAD Modifications	5.6	- 5.6	
Carkeek Park CSO Treatment Plant	4.3	1.8	86
Parallel Fort Lawton Tunnel	17.0	17.0	
Hanford Separation	3.0	→ 3.0	
Green Lake/I-5 Separation	10.2	10.2	2
Diagonal Separation	2.9	2.9	••
Kingdome/Industrial Area Separation	18.9	18.9	
CSO Treatment near Denny Way Regulator (100		49.8	83
Michigan Separation (90 Percent of Basin)	22.8	22.8	
NSA Separation Projects	<u>31.5</u>	31.5	_==
TOTAL	\$187.6	\$182.0	\$ 197
90 PERCENT CSO REDUCTION			
Projects for 75% CSO Reduction	\$187.6	\$182.0	\$ 197
100 mgd Duwamish CSO Treatment Plant	90.0	86.2	123
NSA Separation Projects	3.5	3.5	
Remainder of Michigan Separation	, 1.5	1.5	
University Storage	<u> 28.2</u>	27.6	20
·			
TOTAL	\$ 310.8	\$300.8	\$340

^{* 1985} annual O&M.

Ko C (32) Lux 2000 150 76 182 385 90 308 41

- The combination of projects evaluated in Volume III provides only 74 percent SSA CSO reduction, requiring addition of a small portion of the Michigan separation project to reach 75 percent reduction. This added cost is \$2,400,000.
- The Duwamish secondary plant, using the refined basin data, results in a slightly smaller volume of CSO receiving treatment than predicted in Volume III; thus, associated operation and maintenance costs for this volume have been reduced by \$1,900,000.

The costs for 75 percent SSA CSO reduction for secondary system alternatives 3 and 4 are more than those in Volume III because:

- Based on the revised computer models, the combination of projects in Volume III provides 64 percent SSA CSO reduction. Ninety percent of the Michigan separation project must be added to provide 75 percent CSO reduction. This cost is \$21,800,000.
- The Denny CSO plant under Myrtle Edwards Park is unacceptable to the City. Relocation of the plant to a site on the east side of the railroad tracks has been used to evaluate this alternative. This added cost is \$3,200,000.

For 90 percent SSA CSO reduction, the costs are impacted by the following changes:

- The Michigan separation project greatly reduces the combined sewage quantity at the Duwamish site. For 90 percent CSO control, a Duwamish CSO plant would require return of combined sewage from the Hanford node. This added cost is \$11,000,000.
- DOE has ruled that treated CSO may not be discharged to the Duwamish River and that an outfall must be extended into Elliott Bay. This would add costs to extend the outfall 11,500 feet from the Duwamish site to a point north of Harbor Island and to construct a submarine outfall. The added cost is \$19,000,000.

The cost included in Table 7-2 of Volume III for NSA CSO control was \$30,000,000. This cost increases to \$59,800,000 for secondary system alternatives 1 and 2 for 75 percent volume reduction. The cost for 75 percent NSA CSO control is more than the cost predicted in Volume III because:

- The improved data on NSA basin and system characteristics have resulted in a slightly larger volume of NSA CSO that must be reduced (about another 120 MG/year).
- The NSA projects shown in Volume III provided less than 75 percent NSA CSO volume reduction.
- As shown in Figure 6-1 of Volume III, a small amount of additional NSA CSO reduction is very costly.

The cost for 75 percent CSO volume reduction in the NSA increases to \$61,500,000 for secondary system alternatives 3 and 4. The slight increase, relative to secondary system alternatives 1 and 2, for secondary system alternatives 3 and 4 results from the added NSA CSO control projects required to offset the increased pumping rate at the Interbay pumping station. In the November plan, the Interbay pumping station was shown to be operating at about 100 mgd. Subsequent to the November plan, the secondary team revised the pumping

rate to 133 mgd. This higher rate reduces CSO in the SSA but increases CSO in the NSA, because the higher flow from the pumping station displaces some combined sewage from the NI during storms.

Chapter 5 of this supplement summarizes the effects on pollutant loadings of CSO project combinations that achieve 75 and 90 percent CSO volume reduction.

Chapter 5

CHAPTER 5

COMPARISON OF CSO CONTROL ASPECTS OF SECONDARY SYSTEM ALTERNATIVES

INTRODUCTION

In the preceding chapters, individual, representative CSO control projects were evaluated with economic and non-economic criteria. After screening the projects using non-economic criteria, the remaining projects were combined to achieve the target CSO volume reductions of 75 and 90 percent at the lowest cost for each secondary system alternative. During the course of this planning process and the plan implementation, these representative "building block" projects can be combined in different ways to achieve varying levels of CSO control, either for a given CSO location or on an overall, system-wide basis. This chapter compares the overall CSO control aspects of the five secondary system alternatives based on the representative project combinations developed in Chapters 2 through 4 and summarized in Table 5-1.

COSTS

In the preceding four chapters, present-worth costs have been expressed in terms of 1988 dollars, assuming that each CSO project would be constructed by 1991, the same basis used in Volume III of the November 1985 plan. The economic factors used are also the same ones used in Volume III: discount rate = 10%; inflation = 6%, general; 7%, construction; and 8%, energy. It was recognized in the November plan that it was not practical to actually construct all of the CSO projects by 1991 (illustrative phasing was presented in Chapter 7), and the 1991 date was used solely for comparative purposes. A common completion date allows direct comparison of CSO costs for secondary system alternatives, without question of different CSO phasing assumptions for different secondary system alternatives. Also it allows direct comparison of the relative costs to achieve varying levels of CSO volume reduction, because all of the "building block" project costs are expressed on the same basis.

For purposes of combining the present-worth CSO control costs with the present-worth secondary treatment costs, phased construction of CSO projects has been assumed, as shown in Appendix C. The timing of several CSO projects (i.e., storage in the EBI) is dictated by related elements of the secondary system. As a result, there is a peaking of CSO capital costs in the 1991-1993 period for some cases. In addition to the economic basis described above, secondary present-worth costs were also determined with: discount rate = 8.5%; inflation = 5%, general and construction; and 7%, energy. The alternate set of economic factors is used for CSO projects as well, because the secondary team used them to evaluate their potential effect on present-worth costs. Table 5-1 summarizes the cost of the representative CSO projects for each set of the economic factors. Table 5-2 combines the phased CSO present-worth costs with the phased secondary system present-worth costs, both using 10 percent discount rate and related economic factors.

Figures 5-1 and 5-2 summarize the costs to achieve varying levels of CSO control for each of the secondary system alternatives. Each of the cost curves reaches a point, the "knee of the curve," where costs begin to increase much more sharply than do the related benefits. In the NSA, the knee of the curve occurs at 42 to 50 percent CSO reduction. In the SSA, it occurs at 65 to 75 percent, depending upon the secondary system alternative. If the knee-of-the-curve approach were applied, the following CSO reductions and related costs

would be experienced, using secondary system alternatives 2, 4 and 5 - large Duwamish as examples (refer to Tables 3-2 and 4-1 for projects associated with the knee of the curve):

Secondary System Alternatives	<u>% CSO</u> NSA	Volume R SSA	eduction Overall	Present-Worth CSO Costs (millions, dollars)
2	50	74	69	39
4	42	65	61	51
5 - Large Duwamish	49	72	68	68

As shown in Table 5-1, secondary system alternatives 1 and 2 have the lowest CSO control costs because of the effects of the Duwamish secondary plant. During storms, this plant would treat up to 100 mgd of SSA flow at the Duwamish node. Treatment of 100 mgd would withdraw all of the flow that could be delivered by the sewers upstream of the Duwamish pumping station. This would free up 100 mgd of capacity in the downstream reaches of the EBI. As a result, downstream overflows would be reduced.

In alternatives 3 and 4, modifications to the Interbay pumping station (IBPS) would be made as part of the secondary system modifications that would increase the IBPS output from 100 mgd to 133 mgd. This increased pumping rate would provide low-cost CSO reduction in the SSA to about the 35 percent level. Beyond that level, CSO control would become more costly in secondary system alternatives 3 and 4 than in system alternatives 1 and 2. The higher IBPS rate would cause a slight increase in NSA CSO in system alternatives 3 and 4 that, as shown in Table 5-1, would be offset by increased sewer separation in the NSA.

The CSO control costs for secondary system alternative 5 generally fall between those for alternatives 1 and 2 and alternatives 3 and 4. The costs in the NSA are essentially the same. The differences in the costs in the SSA are affected by the total amount of SSA outlet capacity inherent in the secondary system, which can be summarized as follows:

Secondary System Alternatives 1 and 2	IBPS = 100 mgd Duwamish Sec. Plant = 100 mgd Total = 200 mgd
Secondary System Alternatives 3 and 4	IBPS = 133 mgd
Secondary System Alternative 5 Total Treatment Capacity (Regional System Sized for Storm 2 Flows) Minus NSA Storm 2 Flow Capacity	= 457 mgd = 300 mgd Total = 157 mgd

The capacity for SSA flows in secondary system alternative 5 falls between those for alternatives 1 and 2 and alternatives 3 and 4; therefore, it is not surprising that the CSO control costs also fall between these other alternatives.

CSO Discharges Controlled

Table 5-3 summarizes the effects of the representative project combinations on the CSO volume at each CSO discharge point. Technical memorandum 7 presents detailed information on the CSO discharges at each location for each of the seven design storms.

At 90 percent CSO volume reduction, the effects on individual CSO locations are similar for all secondary system alternatives. However, with the representative projects used for 75 percent CSO volume reduction, the effects on SSA CSO volumes vary. In secondary system alternatives 1 and 2, CSO at Hanford is virtually eliminated, but there is less reduction (about 45 percent) of CSO at Denny Way. In secondary system alternatives 3 and 4 at 75 percent reduction overall, about 95 percent of the CSO at Denny Way is treated, but the reduction of CSO at Hanford is less than in alternatives 1 and 2. In secondary system alternative 5 at 75 percent volume reduction, reductions at Connecticut are greater than in alternative 4. Reductions at Hanford are substantial in all cases (greater than in alternatives 3 and 4), but reductions at Denny Way (none with split Interbay/Duwamish, 50 percent with large Interbay, and 65 percent with large Duwamish) are less than in alternatives 3 and 4.

It is evident from Table 5-3 that the representative project combinations do not greatly reduce CSO at the locations on the west side of the Duwamish River (8th Avenue West, Michigan, Harbor, and Chelan), where smaller CSO volumes occur. A project, West Marginal Way sewers, is described in Volume III (page 5-64) that would nearly eliminate CSO from these locations at a cost of \$10,504,000.

Pollutant Loadings

Using the methodology described in Chapter 2, pollutant loadings were estimated for each discharge location for over 80 project combinations (see technical memorandum 7 for detailed results). Appendix A, Tables 5-4 through 5-6, and Figures 5-3 through 5-10, summarize the results.

Figures 5-3, 5-4 and 5-5 present annual loadings of BOD, suspended solids, and lead at the present time and in the year 2005 for 75 percent CSO volume reduction, using secondary system alternatives 3 and 4 as examples.

There are no CSO discharges to the Central Basin of Puget Sound because combined sewage flows through a treatment plant and an outfall to reach Puget Sound. However, there is a substantial amount of stormwater that is collected from the combined service area and conveyed through West Point to the Central Basin. In the NSA, about 85 percent of the storm runoff from the area served by combined sewers is collected and conveyed to West Point in a year with average rainfall. In the SSA, about 40 percent of the storm runoff from the area served by combined sewers is collected and conveyed to West Point. When combined sewers are separated to eliminate spills of sanitary sewage, stormwater loadings that currently go to West Point and the Central Basin will be discharged from the new separate storm drains to other receiving waters. In exchange, the sanitary sewage that spilled into these other waters during storms will be conveyed to a secondary plant for treatment and discharge to Puget Sound. To enable an evaluation of the net effect of these tradeoffs, the Central Basin loadings associated with stormwaters from the combined sewer areas are included in Tables 5-4, 5-5, and 5-6 and Figures 5-3, 5-4 and 5-5. Unfortunately, the relative amounts of bacteria and virus discharged are not as easily quantifiable as the other pollutants. The fact that sewer separation will greatly reduce the bacteria and virus

discharges from combined sewers is not reflected in the tabulations or graphs.

Figures 5-3, 5-4, and 5-5 also include the loadings from the Renton and West Point plants to provide a general perspective. At the present time, the Renton secondary effluent is discharged to the Duwamish River. In 2005, the Renton effluent will be discharged off Duwamish Head by the effluent transport system now under construction. At the present time, the West Point effluent is primary-treated sewage; in 2005, it will be secondary-treated sewage. As shown in Table 5-4, the CSO loadings would not be substantially different at 90 percent volume reduction than at 75 percent. At 75 percent CSO volume reduction, CSO-related BOD loadings would be reduced by 40 to 54 percent, and suspended solids loadings would be reduced by 30 to 40 percent. At 90 percent, CSO-related BOD loadings would be reduced by 45 to 57 percent, and suspended solids loadings by 37 to 43 percent.

As can be seen from Table 5-4, the overall CSO-related loadings do not vary greatly from one secondary system alternative to another; however, the locations of the discharges vary. Figures 5-6 and 5-7 summarize the loadings to each receiving water. Secondary system alternatives 1, 2, and 5 transfer more of the reduced CSO loadings to the Central Basin of Puget Sound than do secondary system alternatives 3 and 4.

Reductions in metals discharged to waterways are less than reductions in BOD and suspended solids because treatment removes a lower percentage of metals than of BOD and suspended solids. Also, separated stormwater metal concentrations are higher relative to concentrations of stormwater BOD and suspended solids. CSO-related loadings of suspended solids and metals increase over existing loadings for Ship Canal and Lake Union for all secondary alternatives. The increase primarily results from the storm drain loadings from the Green Lake/I-5 separation project. This project would remove a substantial amount of storm runoff from the NI, and the resulting stormwater discharges would slightly increase the solids and metal CSO-related loadings to the Ship Canal and Lake Union. The CSOrelated discharges of bacteria and viruses to the Ship Canal and Lake Union would be substantially decreased and BOD loadings would also decrease. BOD, suspended solids, cadmium, bacteria, and virus discharges related to CSO to the Duwamish and Elliott Bay are reduced by all alternatives. At 75 percent CSO volume reduction, the large Duwamish alternative provides a reduction in CSO-related lead and zinc discharges to Elliott Bay, while all other alternatives provide no reduction or a slight increase. For alternatives 3 and 4, a portion of the CSO-related loads at 75 percent volume reduction would be discharged through a new extended outfall from the Denny Way CSO facility and thus removed from the near-shore area. At 90 percent volume reduction, about two-thirds of the CSO-related loadings in secondary system alternatives 3 and 4 to Elliott Bay would be through extended outfalls from CSO treatment facilities at Denny and at the Duwamish site. To achieve 90 percent CSO volume reduction (Figure 5-7), the added separation used as representative projects for the large Duwamish, makes lead discharges from the large Duwamish alternative to Elliott Bay comparable to all the other alternatives. alternatives reduce loadings of all CSO-related pollutants to the Duwamish.

Considering the total loadings of pollutants from other non-CSO sources, the differences in CSO-related loadings between secondary system alternatives are of questionable significance. For example, a mass balance for pollutants in the Duwamish River prepared as part of the Duwamish Clean Water Plan found that known and/or permitted sources could account for only 1 to 5 percent of the total loads to the river and that CSOs were "minor sources of all pollutants determined except fecal coliforms." Metro's TPPS report found CSO input to Elliott Bay to be a "tiny fraction of the estimated input to the Bay from the Duwamish

River." Small differences in pounds per year of pollutants discharged between secondary alternatives become insignificant as fractions of a percent of inputs to the Duwamish or Elliott Bay.

As discussed in Chapters 2 and 3, storage projects were identified that could be used as an alternative to sewer separation in the Kingdome and Diagonal areas, although at substantially increased costs (about \$49,000,000 greater cost). Figures 5-8 and 5-9 show the effect that use of these two storage projects rather than separation would have on the CSO-related pollutant loadings. As noted above, the significance of the differences is questionable in light of the loadings from other sources. The added cost of the storage option is significant in itself; in addition, commitment to a storage approach results in massive structures that must be sited and which will present long-term operational and maintenance considerations such as odor control, flushing of storage tanks, and impacts at the treatment plants when the stored water is received.

Figure 5-10 compares three secondary system alternatives in terms of cost versus pollutant loading. The costs of various secondary system alternatives to achieve a given pollutant loading can be compared using Figure 5-10. As noted earlier, system comparisons are based on 1991 construction for all CSO projects; thus, the 1991 costs in Figure 5-10 must be adjusted to the phased present-worth basis if they are to be added to the phased secondary Table 5-7 presents a sample cost comparison based on achieving a CSOrelated suspended solids loading of 1,400,000 lbs/year, a 35 percent reduction. Basing system comparisons on equivalent overall CSO-related pollutant loadings rather than volume will narrow the differences in secondary alternative costs. As shown in Table 5-7, rather than using 75 percent volume reduction, the sample suspended solids loading basis would reduce the difference between secondary system alternatives 2 and 4 by about \$60,000,000 and between alternatives 4 and 5 Duwamish by about \$80,000,000. Rather than 90 percent volume reduction, using the suspended solids reduction basis would reduce the difference between alternatives 4 and 5 Duwamish and alternatives 4 and 2 by about \$25,000,000. However, the problem of assigning significance to differences in overall CSO-related loadings has been discussed above. The fact that alternatives 2 and 5 - Duwamish provide greater treatment is a fortuitous benefit inherent in these alternatives. Whether this inherent benefit should be translated into a requirement for other alternatives is another issue. If there is no discernable effect on water quality, then it does not make sense to add extra costs to other alternatives to achieve a level that might be more than is needed.

The information in this CSO plan enables a comparison of CSO control based on volume reduction or pollutant loadings. However, all sources of pollutant loadings to a given water body need to be factored into the consideration of alternatives and levels of control.

OTHER CONSIDERATIONS

Another consideration is that potential¹ regulatory policies may require treatment of discharges from storm drains. Table 5-1 provides a comparison of the relative use of separation in each of the secondary system alternatives. At 75 percent CSO volume reduction, secondary system alternatives 1 and 2, 3 and 4, 5 - large Interbay and 5 - split Interbay/Duwamish all involve the same separation projects noted above, although separation

DOE has advised Metro that no such policies are likely in the foreseeable future --letter dated January 22, 1986, from DOE to Metro.

of a greater portion of the Michigan basin is required for secondary system alternatives 3 and 4. No separation of Michigan and less separation of the Kingdome/industrial area are required for the large Duwamish alternative at 75 percent reduction.

At 90 percent volume reduction, all of the secondary system alternatives include the separation projects for Hanford, Diagonal, Kingdome/industrial area and Michigan (separation of 67 percent of Michigan in secondary system alternatives 1 and 2, 100 percent in all other alternatives) and similar scope of separation in the NSA. Thus, any new regulations affecting monitoring or treatment of stormwater would have a similar effect on all secondary system alternatives at 90 percent CSO volume reduction.

REPRESENTATIVE CSO CONTROL PROJECTS FOR EACH SECONDARY SYSTEM ALTERNATIVE FOR 75 AND 90 PERCENT CSO VOLUME REDUCTION TABLE 5-1

				SECOND	ARY SYS	SECONDARY SYSTEM ALTERNATIVES	TIVES			
CSO CONTROL PROJECT	-1	2	KA	3 & 4	2	5 - Duwamish		5 - Interbay		5 - Solit
	75X	8	75%	X0 6	75%	706	, K	8	Ķ	Š
VSS.				İ	1					2
CATAD Modifications	•	•	•	•	•		•	,		
Hanford Separation	•	•	•	•	•	•	•	•	•	•
Duwamish Secondary Plant	•	•	•	•	•	•	•	•	•	•
Diagonal Separation (1)	•	•	•	•	•	•			•	•
Kingdome/Industrial Area Senaration(1)	•	• (•	•	•	•	•	•	•	•
Michigan Separation(1)	• ?	• į	• }	•	35%	•	•	•	•	•
Department COO Management	40	40	80	•		•	45 %	•	35%	•
Sellif coo il eather		•	•	•	•			•		•
Increase New Regional Interceptor &					•	•	•	•	•	•
Primary Treatment Capacity to 457 mgd)	•	•	•	•	•
Storage in Abandoned Portion				*4.	•					
of Elliott Bay Interceptor					•	•			•	•
Duwamish CSO Treatment										
				•						
NSA AND AND AND AND AND AND AND AND AND AN										
CATAD Modifications	•	•	•							
Green Lake / 1.5 Con	•	•	•	•	•	•	•	•	•	•
יו כרון בחיים כרון	•	•	•	•	•	•	•	•	•	•
Parallel Fort Lawton Tunnel	•	•	•	•				,	•	•
University Storage		•		•		•	•	,		
Separation Projects (2)	55%	62%	58%	757	\ ***	20%	• }	•	• į	•
Storage in Abandoned Fort Lawton Tunnel					3	.	7)0	•	878	*
					•	. :.				
Alki CSO Plant	•	•			•	•	,	,	,	
Alki CSO Equalization			•	•	•	•	•	•	•	•
Carkeek CSO Plant	•	•	•	•		•	,			
		,	•	•	•	•	•	•	•	•
CSO CONTROL COST, PRESENT WORTH (millions, 1988 \$)	ls, 198	3 83								
10% Discount Rate(3)										
1991 Construction	118	216	188	311	153	122	158	244	,	2,0
Phased Construction (4)	104	188	157	526	127	121	5 gC	, c	27.	6 8
8.5% Discount Rate (5)	101	182	151	27,6	1 5	: £	9 5	3 ;	/\$1	90
		!	5	2	9	7/1	2	193	134	<u>\$</u>

⁽¹⁾ Percentage of basin separated to achieve target volume reduction (● = 100%).

⁽²⁾ Percentage of 14 NSA separation project costs required to achieve target volume reduction.
(3) Inflation = 6% general; 7% construction; 8% energy.

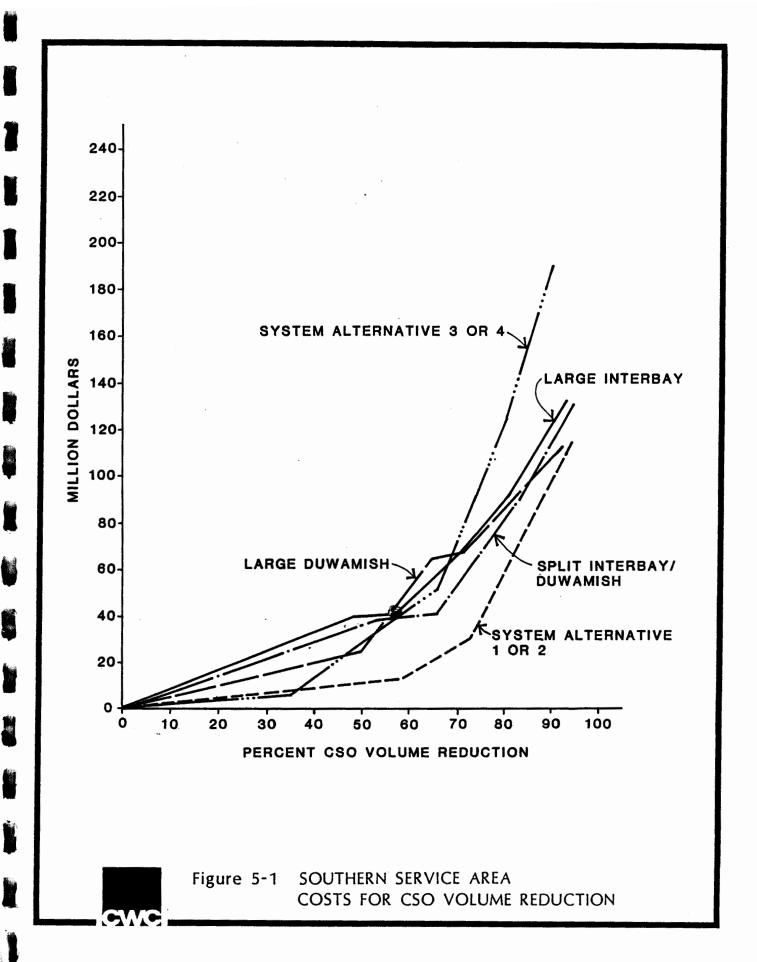
⁽⁴⁾ Expenditures for CSO projects, 1987-2005, per Appendix C.(5) Inflation = 5% general and construction; 7% energy.

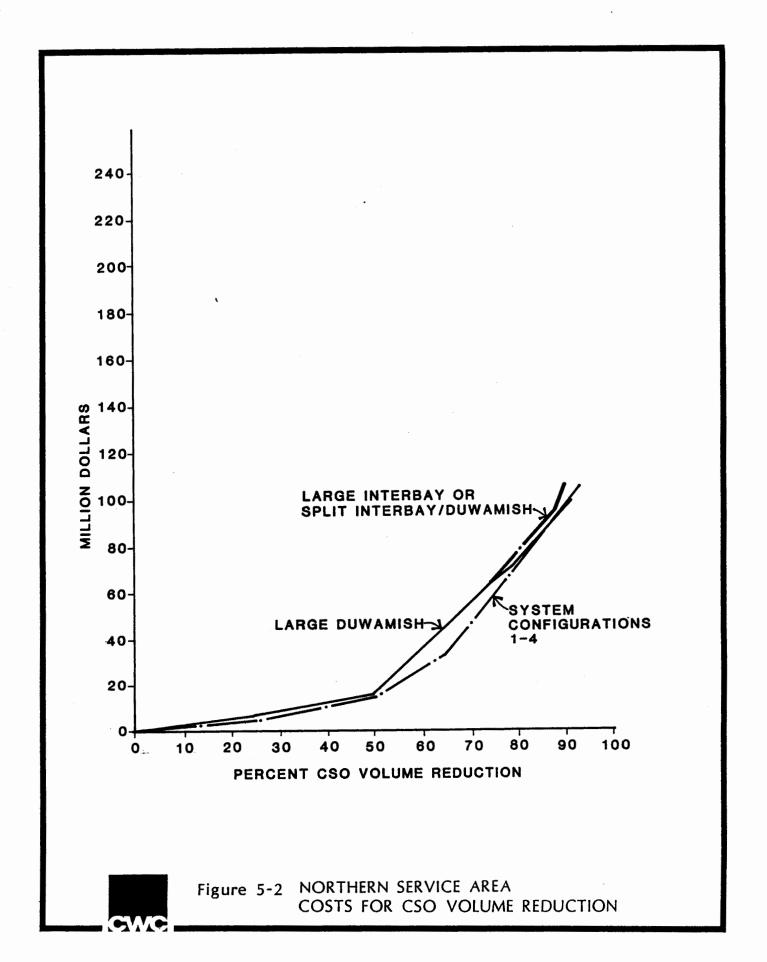
TABLE 5-2
COSTS OF SECONDARY TREATMENT AND CSO CONTROL

1988 Present-Worth Costs (in \$1,000,000)(1)

Secondary System	Secondary	· CSO Co	sts for ne Reduction		ram Costs for
Alternatives	Treatment Costs	<u>75%</u>	<u>90%</u>	<u>75%</u>	<u>90%</u>
1	1,416	104	188	1,520	1,604
2	1,232	104	188	1,336	1,420
3	1,309	157	256	1,466	1,565
4	1,116	157	256	1,273	1,372
5 - Large Duwamish	1,467	127	177	1,594	1,644
5 - Large Interbay	1,389	128	200	1,517	1,589
5 - Split Interbay/				•	,
Duwamish	1,506	137	206	1,643	1,712

⁽¹⁾ Discount rate = 10%; inflation = 6% general, 7% construction; 8% energy. Phased expenditures for CSO projects per schedules in Appendix C.





EFFECTS OF REPRESENTATIVE CSO PROJECT COMBINATIONS ON INDIVIDUAL CSO DISCHARGES (Average Rainfall, MG/Year)

						y oso	CSO Volume With	۽				
					Secon	Secondary Alternative, Year 2005	rnative,	Year 20	05			
	Existing					. 2	5 - Large	5 .	5 - Large	5 -	5 - Split	
CSO Location	Annual	-1	1 & 2	2	7	DUME	Duwamish	I	Interbay	Interba	Interbay/Duwamish	_
	Volume (MG)	75%	208	75%	80%	75%	8	75%	808	75%	X06	
SSA				, Kac-211		Kac. 14						
Hanford	089	19	91	241	7	8	70	8	105	35	0	
Denny	376	196	17	1	17	13	7	187	5	234	2	
Michigan	250	151	65	22	7	≅	0	88	0	62	0	The state of the s
Lander	215	8	~	2		%	0	54	0	0	0	
Duwamish P. Sta.	130	•	0	4	0	0.7	9.0	M	4	45	14	
Connecticut	8	16	9	8	26	8	~	∞	0.7	9.0	0.1	
King	2	19	0	0	0	37	16	82	13	0	0	
Harbor	55	37	38	17	82	27	\$2	22	31	E	34	
Brandon	35	ĸ	82	82	81	31	=	58	14	88	9	
Chelan	52	9	. •	~	'n	10	٥	_	5	12	ħ	
8th Ave.	15	5	Ξ	Ξ	∞	=	5	7	5	13	7	
Norfolk	7	4	4	4	4	4	4	4	4	4	4	
W. Michigan	-2	0.7	0.8	0.8	0.5	9.0	9.0	9.0	0.8	0.7	9.0	
	1,941	787	193	485	194	485	194	206	506	482	171	
NSA												
University	200	8	6	8	6	35	6	45	72	57	5	
3rd Ave. W.	105	4	4	, LO	4	~	M		; -	. ~	۲ م	
Bailard	8	4	5	•	· w	.	M	. 10	. ~	. 10	۱ ۸	
Montlake	07	13	7	13	7	=	ø	92	4	8		
Dexter	12	2	M	īV	M	'n	М	٥	2	٥	M	
Canal St.	6	2	7	7	7	4	-	M	-	8	-	
30th Ave. N.E.	7	2	7	2	7	-	-	-	-	-	_	
Belvoir	4	7.0	7.0	7.0	9.0	9.0	9.0	9.0	9.0	9.0	9.0	
New NSA Interbay P.Sta.	.Sta::	9	٩	0	0	16	M	21	9	21	•	
	897	%	75	8	75	118	45	118	75	118	7.	

V li e

TABLE 5-4

STORM RELATED LOADINGS FOR OVERALL SYSTEM (1,000 lbs/year, average rainfall)
FOR SECONDARY SYSTEM ALTERNATIVES AT 75 AND 90 PERCENT CSO VOLUME REDUCTIONS

	<u>2-1/0</u>	598	1,256	8.1	0.013	8.7	
ction	2:1	623	1,328	8.7	0.085	9.6	
90% Vol. Reduction	2-0	533	1,292	6.9	0.073	9.1	
X06	3-4	634	1,315	8.6	0.089	4.6	
-	1:2	929	1,216	8.2	0.080	8.7	
	<u>51/0</u>	929	•	7.8	0.119	8.7	
ction	2-1	759	1,291	8.2	0.083	9.0	
75% Vol. Reduction	2.0	225	1,281	7.8	0.067	80 57	
75%	3-4	729	1,366	8.6	0.092	9.5	
	1:2	629	1,305	8.4	0.080	9.0	
2 9	Control	1,236	2,119	12.5	0.150	13.1	
		908	SS	æ	8	۲۶	

CSO-RELATED POLLUTANTS AND ANNUAL AVERAGE LOADINGS (LBS/YEAR) AND FLOWS (MG/YEAR)⁽¹⁾⁽²⁾ 75 PERCENT CSO VOLUME REDUCTION LOCATION OF CSO DISCHARGES AND TABLE 5-5

	Related	S CSO				•	
۵	Pollistant	1	•		> . Large	5 · Large	5 - Split
-1	OI LUCAINE	COULTO	1 6 2	3 & 4	Duwamish	Interbay	Interbay/Duwamish
•	Flow (MG)	1,406	253	373	300	286	Ç.
	800	499,000	113,700	249,200	106,000	124.700	170 800
	SS	854,000	304,900	532,000	307,000	363,000	370.500
	Cadmium	27	2	%	2	2	72
	Lead	3,500	1,710	2,770	1.700	2,140	2 0%0
ì	Zinc	3,680	1,860	2,990	1,900	2,280	2,360
-	ON (MG)	535	123	112	185	222	230
	80	467,000	101,300	165,900	62,000	92.000	136 350
	SS :	519,000	274,300	300, 100	145,000	265,000	324,400
-	Cadmica	22	2	8	2	10	25
	Lead	1,930	2,070	2,220	26	2.040	1 060
	Zinc	2,230	2,150	2,405	-	2.115	27.75
<u> </u>	(MG)	424	*	6	116	71.	71,
	8	83,000	35,000	55,000	63,000	52.400	007 25
•	SS :	236,000	341,000	335,000	367,000	307,400	307,400
•		- 1	•	•	5	•	€
	Lead	930	1,610	1,615	1,780	1,440	1,440
•	7100	940	1,590	1,595	1,760	1,420	1.420
I	(MC)	5	~	~	~	~	^
	8 3	3,500	7 00	007	400	700	007
•	SS:	9,300	1,200	1,200	1,200	1,200	1.200
J		0	0	0	•		0
	Lead	58	~	•	7	•	• •
	Zinc	S S	•	4	. 4	• •	•
ī	Flow (MG)	4,200	:	• ;	•	•	•
	908	184,000	388,000	225,000	270 000	278	;
	SS	501,000	383 000	200,000	240,000	200,000	316,000
ä	dimi	*	00,000	DDC 1007	401,000	354,000	315,000
•	Pag 1	8 5	Ŧ (22	3.	37	7,5
		0, 100	2,990	2,120	3,330	2,650	2,310
	2017	6,325	3,400	2,500	3,645	3,200	2,680

those resulting from stormwater which is conveyed to West Point, treated, and discharged to Central Basin. Future Central Basin annual secondary effluent loadings to Central Basin would be: flow = 87,600 MG/year; BOD = 11,000,000 lbs; SS = 18,250,000 lbs; loads include those from stormwater plus the CSO loads which are transferred to a secondary plant as a result of CSO projects. (1) Based on annual average flow of 240 mgd and Renton secondary effluent composition shown in TPPS in Table D-5, IPPS Report A1, lead = 32,900 lbs; cadmium = 1,460 lbs; zinc = 35,100 lbs. Loadings shown in this table for "No CSO Control, Existing" are Flow volumes are untreated CSO only. Loadings include CSO-related loads discharged from outfalls from treatment facilities 8

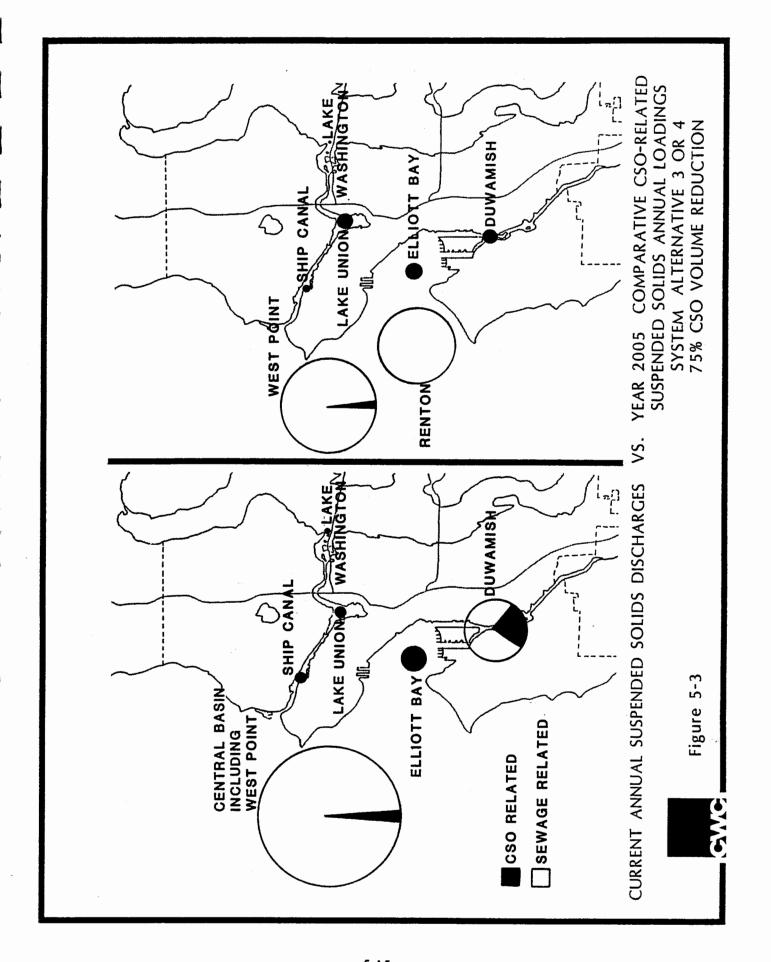
loads in remaining spills of untreated CSO, and loads from separated stormwater.

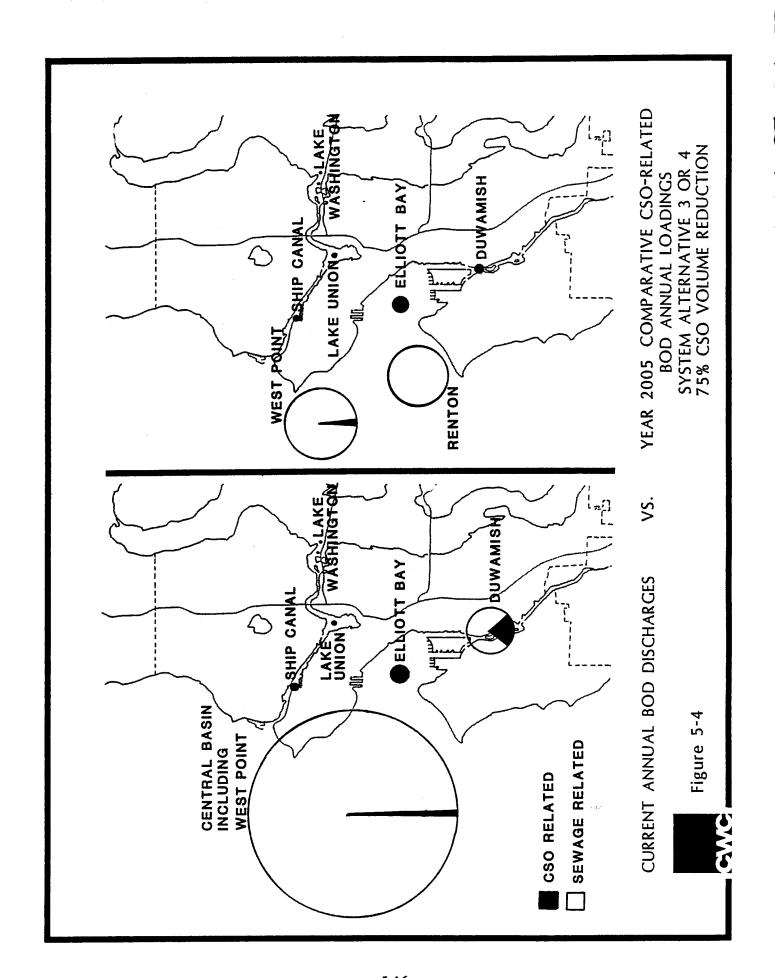
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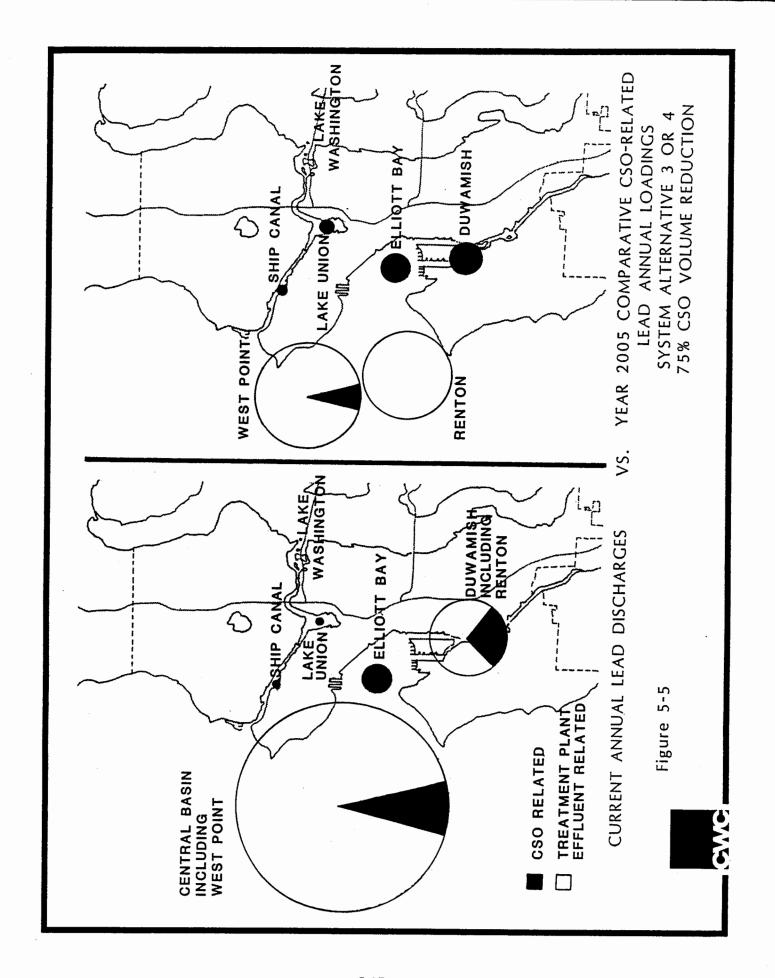
TABLE 5-6
LOCATIONS OF CSO DISCHARGES AND
CSG-RELATED POLLUTANT AND ANNUAL AVERAGE LOADINGS
(LBS/YEAR) AND FLOW (MG/YEAR)⁽¹⁾⁽²⁾
90 PERCENT CSO VOLUME REDUCTION

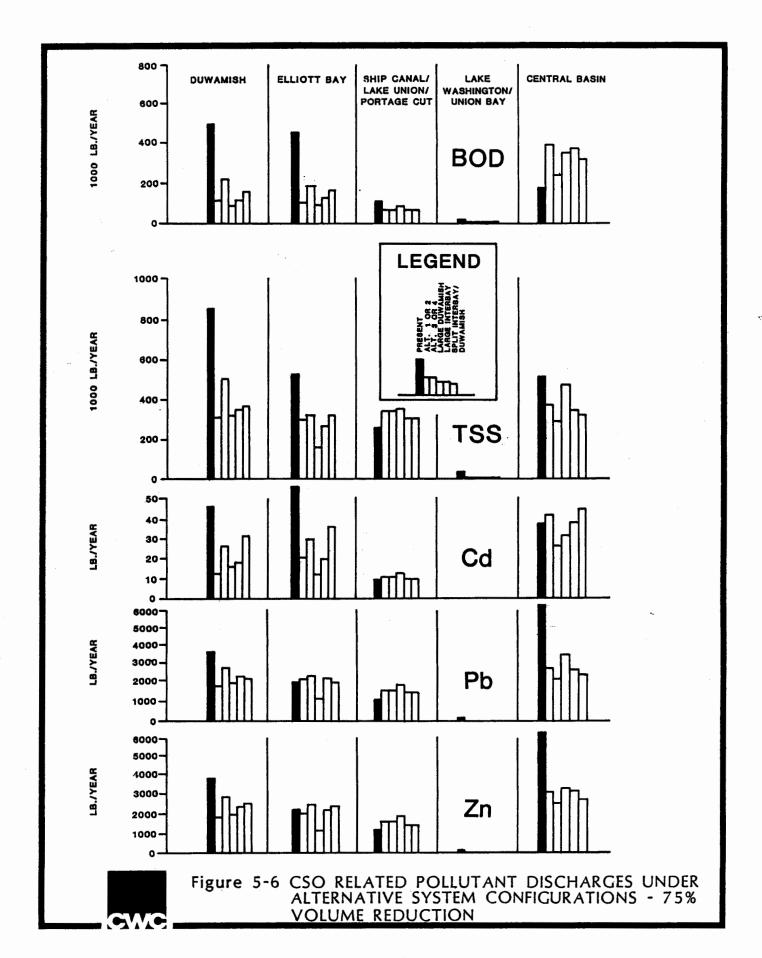
					. 7	A . 1 acae	5 . Col (+
Receiving	Kelated	No CSO			ague . c		3136
Water	Pollutant	Control	1 & 2	3.6.4	Duwamish	Interbay	Interbay/Duwamish
Duwamish	FLOW (MG)	1,406	170	8	\$	8	101
	90	499,000	74,300	81,300	88,200	114,000	114,000
	SS	854,000	286,000	310,400	321,000	369,000	338,000
	Cadmium	24	2	2	11	19	23
	Lead	3,500	1,940	2,400	2,370	2,525	2,390
	Zinc	3,680	2,040	2,340	2,370	2,545	2,435
Elliott Bay	FLOW (MG)	535	2	112	8	27	2
,	800	467,000	83,500	276,000	20,000	79,300	113,000
	SS	519,000	215,900	383,000	176,000	213,000	255,000
	Cadaium	25	6	37	32	8 1	58
	Lead	1,930	1,690	2,610	1,730	1,710	1,830
	zinc	2,230	1,995	2,965	1,805	1,995	2,090
Ship Canal/	Flow (MG)	454	9	9	9	9	9
Lake Union/	00	83,000	49,100	50,500	52,000	63,000	24,000
Portage Cut	SS	236,000	323,000	329,000	340,000	402,000	354,000
	Cadmium	_	٥	۰	2	Ξ	2
	Lead	930	1,640	1,640	1,695	2,050	1,780
	Zinc	076	1,620	1,620	1,675	2,040	1,760
Lake Washington/	Flow (MG)	13	~	~	~	8	~
Union Bay	808	3,500	700	007	007	007	007
	SS	9,300	1,200	1,200	1,200	1,200	1,200
	Cedmium	•	0		•	0	0
	Lead	58	4	•	•	•	∢.
;	Zinc	30	•	•	•	•	•
Central Basin ⁽¹⁾	Flow (MG)	4,200	:	:	:		
	008	184,000	392,000	226,000	343,000	367,000	316,000
	SS	501,000	390,000	291,500	453,000	342,000	308,000
	Cadmium	8	07	72	E	37	24
	Lead	6,160	2,900	2,120	3,100	2,400	2,140
	;			001	022 2	2 070	027 6

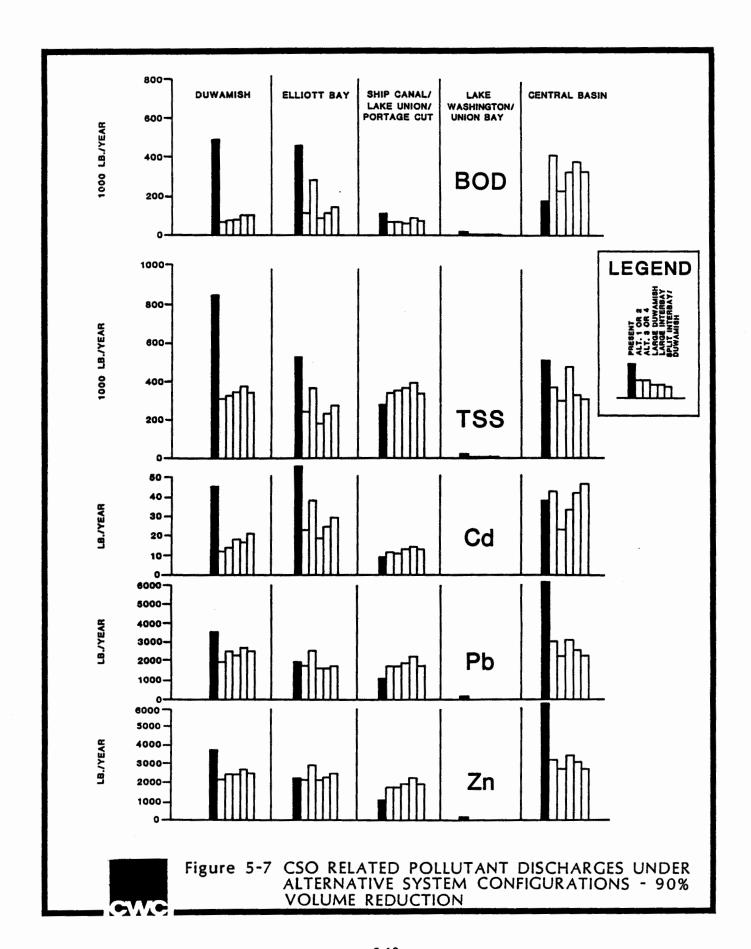
those resulting from stormwater which is conveyed to West Point, treated, and discharged to Central Basin. Future Central Basin annual secondary effluent loadings to Central Basin would be: flow * 87,600 MG/year; BOD = 11,000,000 lbs; SS = 18,250,000 lbs; loads include those from stormwater plus the CSO loads which are transferred to a secondary plant as a result of CSO projects. (1) Based on annual average flow of 240 mgd and Renton secondary effluent composition shown in TPPS in Table D-5, TPPS Report A1, tead = 32,900 lbs; cadmium = 1,460 lbs; zinc = 35,100 lbs. Loadings shown in this table for "No CSO Control, Existing" are Flow volumes are untreated CSO only. Loadings include CSO-related loads discharged from outfalls from treatment facilities loads in remaining spills of untreated CSO, and loads from separated stormwater. €

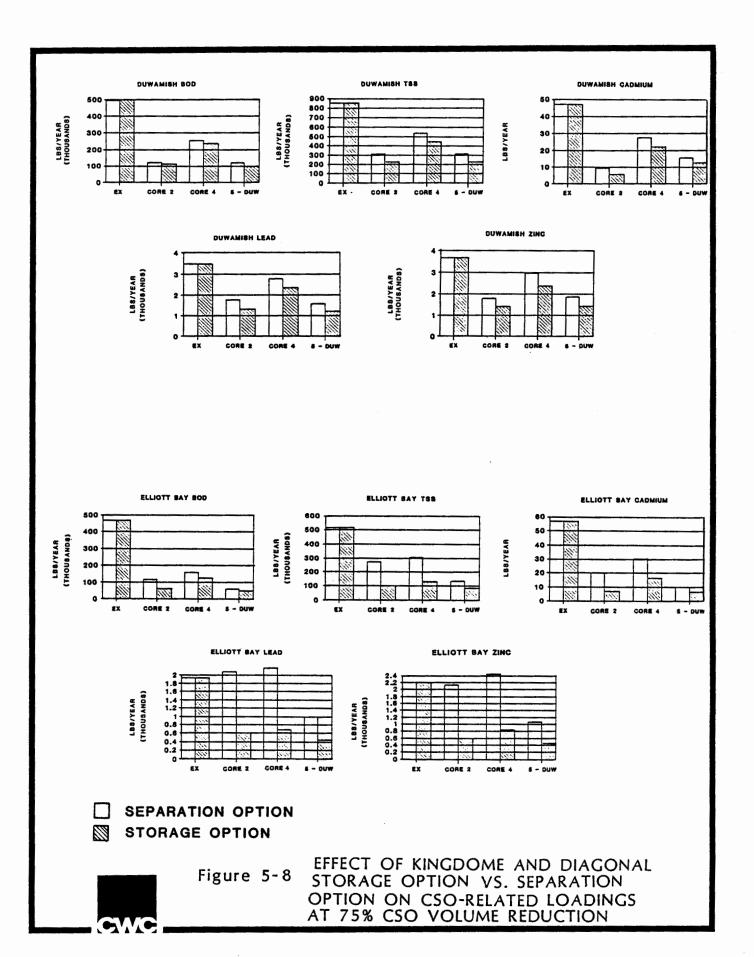


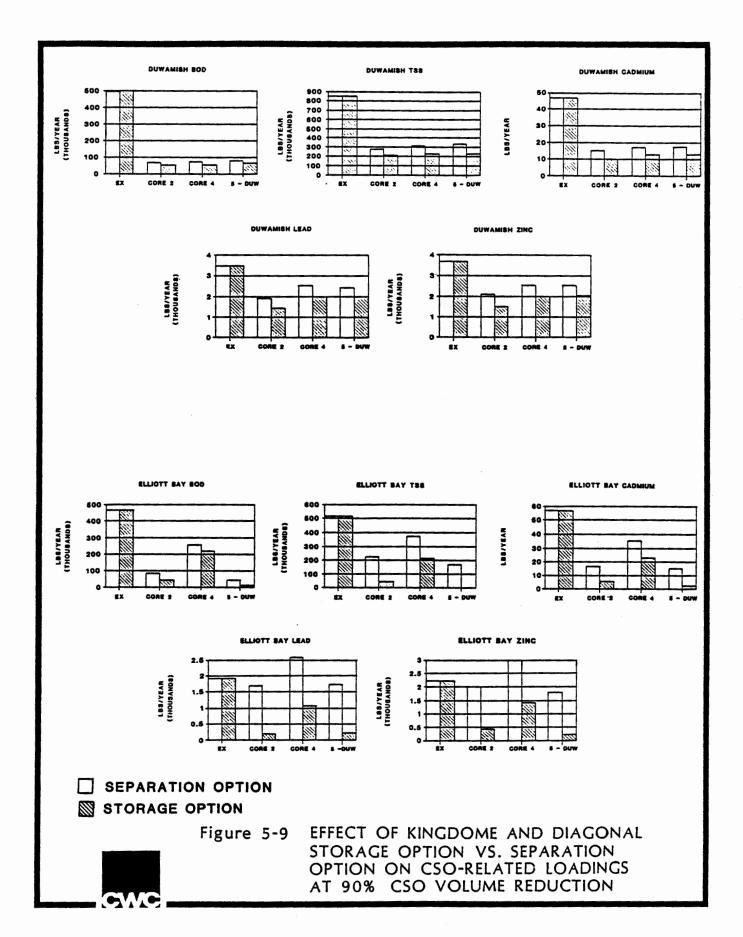












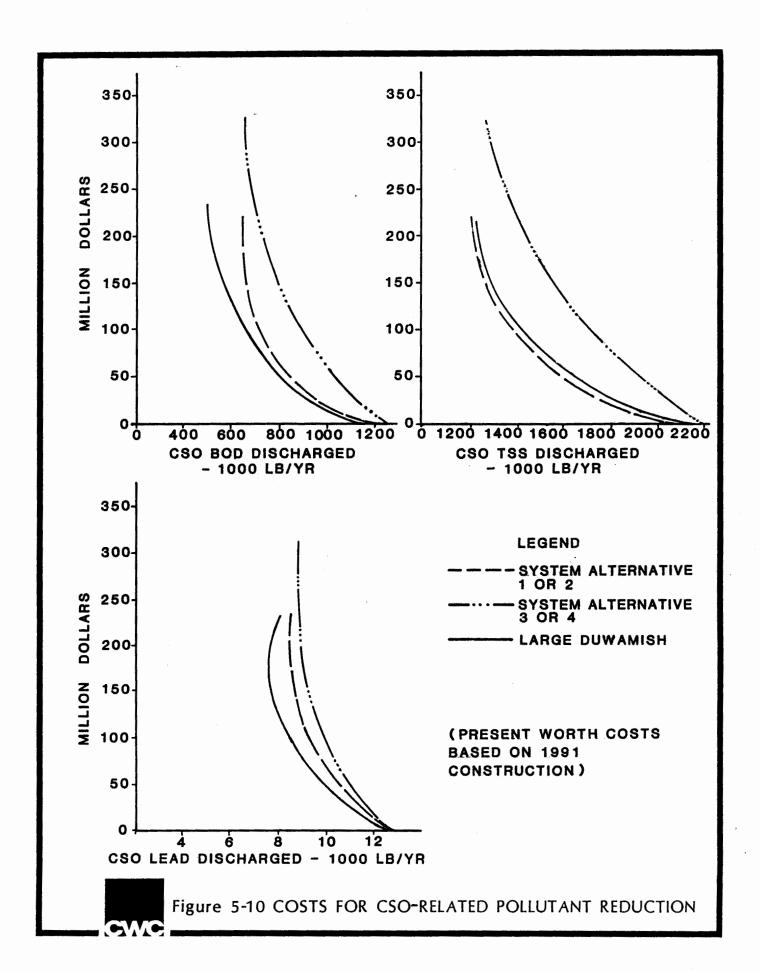


TABLE 5-7

EFFECT OF COMPARING CSO ALTERNATIVES ON BASIS OF POLLUTANT LOADINGS
RATHER THAN VOLUME REDUCTION

	CSO Control Co	osts ⁽¹⁾ at Redu	ctions of (\$ millions)
Secondary System Alternative	75% <u>Volume</u>	90% <u>Volume</u>	35% Suspended Solids
4	186	310	225
5 - Duwamish	153	221	110
2	118	216	100
4 minus 5 Duwamish	33	89	115
4 minus 2	68	94	125

⁽¹⁾ Based on 1991 construction.

APPENDIX A

EFFECTS OF CSO CONTROL PROJECT COMBINATIONS ON CSO VOLUME AND POLLUTANT LOADING

•

TABLE A-1 SECONDARY SYSTEM ALTERNATIVES 1 AND 2 CSO POLLUTANT ANNUAL⁽¹⁾ LOADINGS, 75 PERCENT CSO VOLUME REDUCTION

Receiving Water	Untreated Volume			Pounds		
& Discharge Location	<u>(MG)</u>	BOD	<u>SS</u>	<u>Cadmium</u>	Lead	Zinc
Duwamish	253	82,900	126,000	3.0	630	600
Hanford Storm Drain ⁽²⁾		19,900	87,100	3.2	630	640
Diagonal Storm Drain ⁽²⁾		7,600	82,000	3.1	330	520
Michigan Storm Drain ⁽²⁾		3,300	9,800	0.7	120	100
Elliott Bay	231	61,300	103,300	7.0	590	585
King Storm Drain ⁽²⁾		40,000	171,000	12.6	1,480	1,565
Ship Canal/						
Lake Union/Portage Cut	94	14,000	52,200	1.1	170	170
NSA Storm Drains	•	20,000	114,000	3.5	650	650
Green Lake/I-5 Drain		20,700	175,600	4.7	790	770
Lake Washington/Union Bay	2	400	1,200	0	4	4
Central Basin (3)		363,800	295,400	37.0	1,975	2,200

Based upon a year with average rainfall.
 Load from separated stormwater.
 CSO-related loads after being conveyed and treated at a central treatment facility.

TABLE A-2 SECONDARY SYSTEM ALTERNATIVES 3 AND 4 CSO POLLUTANT ANNUAL⁽¹⁾ LOADINGS, 75 PERCENT CSO VOLUME REDUCTION

Receiving Water	Untreated Volume			Pounds		
& Discharge Location	(MG)	BOD	SS	Cadmiun	n <u>Lead</u>	Zinc
Duwamish	373	191,700	275,300	13.0	730	950
Hanford Storm Drain ⁽²⁾		19,900	87,100	3.2	630	640
Diagonal Storm Drain ⁽²⁾		7,600	82,000	3.1	330	520
Michigan Storm Drain ⁽²⁾	••	30,000	88,000	6.6	1,080	880
Elliott Bay	112	74,600	94,800	12.1	390	470
King Storm Drain ⁽²⁾	••	40,000	171,000	12.6	1,480	1,565
Denny CSO Outfall	••	51,200	34,300	5.0	350	370
Ship Canal/						
Lake Union/Portage Cut	97	14,300	45,100	1.2	175	175
NSA Storm Drains ⁽²⁾	4040	° ^{/<,} 20,000 ⁵⁷	8 K 114,000	1.6× 3.5	295× 650	295 650
Green Lake/I-5 Drain	••	20,700	175,600	4.7	790	770
Lake Washington/Union Bay	2	400	1,200	0	4	4
Central Basin ⁽³⁾		204,000	197,900	24.0	1,300	1,500

Based upon a year with average rainfall.
 Load from separated stormwater.
 CSO-related loads after being conveyed and treated at a central treatment facility.

TABLE A-3 SECONDARY SYSTEM ALTERNATIVE 5
LARGE DUWAMISH--CSO POLLUTANT ANNUAL⁽¹⁾ LOADINGS
75 PERCENT CSO VOLUME REDUCTION

Receiving Water	Untreated Volume			Pounds		
& Discharge Location	(MG)	BOD	<u>ss</u>	<u>Cadmium</u>	Lead	Zinc
Duwamish Hanford Storm Drain ⁽²⁾ Diagonal Storm Drain ⁽²⁾	300 	78,300 19,900 7,600	138,000 87,100 82,000	10.0 3.2 3.1	740 630 330	750 640 520
Elliott Bay King Storm Drain ⁽²⁾	185	48,000 14,000	85,000 60,000	6.0 4.4	450 520	460 550
Ship Canal/ Lake Union/Portage Cut NSA Storm Drains ⁽²⁾ Green Lake/I-5 Drain	116 	18,700 24,000 20,700	54,800 137,000 175,600	1.4 4.2 4.7	210 780 790	210 780 770
Lake Washington/Union Bay	2	400	1,200	0	4	4
Central Basin ⁽³⁾		246,800	363,400	26.0	2,125	2,200

Based upon a year with average rainfall.
 Load from separated stormwater.

⁽³⁾ CSO-related loads after being conveyed and treated at a central treatment facility.

TABLE A-4 SECONDARY SYSTEM ALTERNATIVE 5 LARGE INTERBAY--CSO POLLLUTANT ANNUAL⁽¹⁾ LOADINGS, 75 PERCENT CSO VOLUME REDUCTION

Receiving Water	Untreated Volume			Pounds		
& Discharge Location	(MG)	BOD	SS	Cadmium	<u>Lead</u>	Zinc
<u>Duwamish</u>	284	82,200	149,000	9.0	640	680
Hanford Storm Drain ⁽²⁾		19,900	87,100	3.2	630	640
Diagonal Storm Drain ⁽²⁾		7,600	82,000	3.1	330	520
Michigan Storm Drain ⁽²⁾	••	15,000	45,000	3.3	540	440
Elliott Bay	222	52,000	94,000	6.0	560	550
King Storm Drain ⁽²⁾	••	40,000	171,000	12.6	1,480	1,565
Ship Canal/						
Lake Union/Portage Cut	116	18,700	54,800	1.4	210	210
NSA Storm Drains ⁽²⁾		13,000	77,000	2.4	440	440
Green Lake/I-5 Drain	••	20,700	175,600	4.7	790	770
Lake Washington/Union Bay	2	400	1,200	0	4	4
Central Basin ⁽³⁾		343,800	265,700	33.0	1,680	2,035

Based upon a year with average rainfall.
 Load from separated stormwater.

⁽³⁾ CSO-related loads after being conveyed and treated at a central treatment facility.

TABLE A-5 SECONDARY SYSTEM ALTERNATIVE 5 SPLIT INTERBAY/DUWAMISH--CSO POLLUTANT ANNUAL $^{(1)}$ LOADINGS, 75 PERCENT CSO VOLUME REDUCTION

Receiving Water	Untreated Volume			Pounds		
& Discharge Location	(MG)	BOD	SS	Cadmium	Lead	Zinc
<u>Duwamish</u>	252	131,600	167,400	25.0	660	860
Hanford Storm Drain ⁽²⁾		19,900	87,100	3.2	630	640
Diagonal Storm Drain ⁽²⁾		7,600	82,000	3.1	330	520
Michigan Storm Drain ⁽²⁾		11,700	34,000	2.6	420	340
Elliott Bay	230	96,350	153,400	22.0	480	670
King Storm Drain ⁽³⁾	••	40,000	171,000	12.6	1,480	1,565
Ship Canal/						
Lake Union/Portage Cut	116	18,700	54,800	1.4	210	210
NSA Storm Drains ⁽²⁾		13,000	77,000	2.4	440	440
Green Lake/I-5 Drain	••	20,700	175,600	4.7	790	770
Lake Washington/Union Bay	2	400	1,200	0	4	4
Central Basin ⁽³⁾		291,400	226,100	58.0	1,315	1,490

Based upon a year with average rainfall.
 Load from separated stormwater.

⁽³⁾ CSO-related loads after being conveyed and treated at a central treatment facility.

TABLE A-6 SECONDARY SYSTEM ALTERNATIVES 1 AND 2 CSO POLLUTANT ANNUAL⁽¹⁾ LOADINGS, 90 PERCENT CSO VOLUME REDUCTION

Receiving Water	Untreated Volume			Pounds		
& Discharge Location	(MG)	BOD	SS	Cadmium	Lead	Zinc
<u>Duwamish</u>	170	24,800	51,900	2.0	200	240
Hanford Storm Drain ⁽²⁾		19,900	87,100	3.2	630	640
Diagonal Storm Drain ⁽²⁾	••	7,600	82,000	3.1	330	520
Michigan Storm Drain ⁽²⁾	••	22,000	65,000	4.7	780	640
Elliott Bay	23	10,300	13,500	2.0	50	70
King Storm Drain ⁽²⁾	. ••	40,000	171,000	12.6	1,480	1,565
Denny CSO Outfall	••	33,200	31,400	4.0	160	360
Ship Canal/						
Lake Union/Portage Cut	40	5,800	18,400	0.4	80	80
NSA Storm Drains ⁽²⁾	••	22,600	129,000	4.0	770	770
Green Lake/I-5 Drain	••	20,700	175,600	4.7	790	770
Lake Washington/Union Bay	2	400	1,200	0	4	4
Central Basin ⁽³⁾	**	371,000	309,000	37.0	2,055	2,280

Based upon a year with average rainfall.
 Load from separated stormwater.

⁽³⁾ CSO-related loads after being conveyed and treated at a central treatment facility.

TABLE A-7 SECONDARY SYSTEM ALTERNATIVES 3 AND 4 CSO POLLUTANT ANNUAL⁽¹⁾ LOADINGS, 90 PERCENT CSO VOLUME REDUCTION

Receiving Water	Untreated Volume			Pounds		
& Discharge Location	(MG)	BOD	SS	Cadmium	Lead	Zinc
<u>Duwamish</u>	82	20,500	43,000	2.0	240	200
Hanford Storm Drain ⁽²⁾		19,900	87,100	3.2	630	640
Diagonal Storm Drain ⁽²⁾		7,600	82,000	3.1	330	520
Michigan Storm Drain ⁽²⁾	••	33,300	97,700	7.3	1,200	980
Elliott Bay	112	74,600	94,800	12.1	390	470
King Storm Drain ⁽²⁾		40,000	171,000	12.6	1,480	1,565
Denny CSO Treatment Pl	ant	51,200	34,300	5.0	350	370
Duwamish CSO Treatmen		110,200	83,200	7.0	390	560
Ship Canal/						
Lake Union/Portage Cut	40	5,800	18,400	0.4	80	80
NSA Storm Drains ⁽²⁾		24,000	135,000	4.2	770	770
Green Lake/I-5 Drain		20,700	175,600	4.7	790	770
Lake Washington/Union Bay	2	400	1,200	0	4	4
Central Basin ⁽³⁾		207,000	204,900	24.0	1,325	1,540

⁽¹⁾ Based upon a year with average rainfall.

 ⁽²⁾ Load from separated stormwater.
 (3) CSO-related loads after being conveyed and treated at a central treatment facility.

TABLE A-8 SECONDARY SYSTEM ALTERNATIVE 5
LARGE DUWAMISH--POLLUTANT ANNUAL⁽¹⁾ LOADINGS,
90 PERCENT CSO VOLUME REDUCTION

Receiving Water	Untreated Volume			Pounds		
& Discharge Location	(MG)	BOD	SS	Cadmium	Lead	Zinc
Duwamish Hanford Storm Drain(2) Diagonal Storm Drain(2)	104 	27,400 19,900 7,600	54,700 87,100 82,000	3.0 3.2 3.1	210 630 330	230 640 520
Michigan Storm Drain ⁽²⁾		33,300	97,700	7.3	1,200	980
Elliott Bay King Storm Drain ⁽²⁾	90 	10,300 40,000	5,500 171,000	2.0 12.6	250 1,480	240 1,565
Ship Canal/ Lake Union/Portage Cut NSA Storm Drains ⁽²⁾ Green Lake/I-5 Drain	40 	5,800 25,500 20,700	18,400 146,000 175,600	0.4 4.5 4.7	80 825 790	80 825 770
Lake Washington/Union Bay	2	400	1,200	0	4	4
Central Basin (3)		258,730	377,440	28.0	2,281	2,388

Based upon a year with average rainfall.
 Load from separated stormwater.
 CSO-related loads after being conveyed and treated at a central treatment facility.

TABLE A-9 SECONDARY SYSTEM ALTERNATIVE 5
LARGE INTERBAY--CSO POLLUTANT ANNUAL⁽¹⁾ LOADINGS,
90 PERCENT CSO VOLUME REDUCTION

Receiving Water	Untreated Volume			Pounds		
& Discharge Location	(MG)	BOD	SS	Cadmium	Lead	Zinc
<u>Duwamish</u>	179	53,000	102,000	5.0	365	405
Hanford Storm Drain ⁽²⁾	••	19,900	87,100	3.2	630	640
Diagonal Storm Drain ⁽²⁾		7,600	82,000	3.1	330	520
Michigan Storm Drain ⁽²⁾		33,300	97,700	7.3	1,200	980
Elliott Bay	27	6,100	10,900	1.0	70	70
King Storm Drain ⁽²⁾		40,000	171,000	12.6	1,480	1,565
Denny CSO Outfall		33,200	31,400	4.0	160	360
Ship Canal/						
Lake Union/Portage Cut	40	5,800	18,400	0.4	80	80
NSA Storm Drains ⁽²⁾		36,500	208,000	6.4	1,180	1,190
Green Lake/I-5 Drain		20,700	175,600	4.7	790	770
Lake Washington/Union Bay	2	400	1,200	0	4	4
Central Basin ⁽³⁾		349,350	272,600	34.0	1,750	2,125

Based upon a year with average rainfall.
 Load from separated stormwater.

⁽³⁾ CSO-related loads after being conveyed and treated at a central treatment facility.

SECONDARY SYSTEM ALTERNATIVE 5
SPLIT INTERBAY/DUWAMISH--CSO POLLUTANT ANNUAL⁽¹⁾ LOADINGS,
90 PERCENT CSO VOLUME REDUCTION

Receiving Water	Untreated Volume			Pounds		
& Discharge Location	(MG)	BOD	SS	Cadmium	Lead	Zinc
<u>Duwamish</u>	101	52,700	71,000	8.5	230	295
Hanford Storm Drain ⁽²⁾		19,900	87,100	3.2	630	640
Diagonal Storm Drain ⁽²⁾		7,600	82,000	3.1	330	520
Michigan Storm Drain ⁽²⁾		33,300	97,700	7.3	1,200	980
Elliott Bay	70	29,500	47,500	6.7	149	206
King Storm Drain ⁽²⁾		40,000	171,000	12.6	1,480	1,565
Denny CSO Outfall		44,000	37,000	9.0	200	320
Ship Canal/						
Lake Union/Portage Cut	40	5,800	18,400	0.4	80	80
NSA Storm Drains ⁽²⁾		28,000	160,000	4.9	910	910
Green Lake/I-5 Drain		20,700	175,600	4.7	790	770
Lake Washington/Union Bay	2	400	1,200	0	4	4
Central Basin ⁽³⁾		297,600	233,300	59.0	1,395	1,520

⁽¹⁾ Based upon a year with average rainfall.

⁽²⁾ Load from separated stormwater.

⁽³⁾ CSO-related loads after being conveyed and treated at a central treatment facility.

APPENDIX B

COSTS OF INCREASING
SIZE OF REGIONAL CONVEYANCE
AND TREATMENT
FOR
CSO REDUCTION

(Costs calculated by secondary planning team)

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STORM 6
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(mgd) (inch-feet) 87,856 326,075 765,936 451,992 109,510 268,967 53,969 146.343 841,142 \$5.23 \$4.85 \$91.493 \$26A.137 1,065,949 3,646,147 8 g 8 8 8 8 171,050 호 ≊ 5 gg 11 Add'1 ||Capacity || (mgd) Additional 11 Storm Capacity 11Capacity (inch-feet)11 (mgd) ã 333 75 745,924 \$77.532 H 622.932 H 412,575 132,935 367,155 211,447 134,848 287,730 679, 338 8, 93, 242,866 ¥,299 \$113.852 \$41.548 87,856 3,300,057 [1] STORM 5 Additional Capacity (agd) 936, ₹ Ø 310 8 E Ļ Capacity (Capacity (irch-feet); (mgd) || Add'| ||Capacity || (mgd) ş 죓 亞 Ħ U 563,236 126,178 237,218 55,542 69,607 60,540 482,666 \$64.620 \$26.884 159,253 126,963 1,84 87,856 1,873,046 \$42,230 6133.734 Cost to 1 Moditional Capacity (sigd) 78,950 28 ₹ ¥ ₹ ₹ 8 X ANALYSIS Capacity || Storm R Capacity || Capacity (inch-feet)|| (mgd) || Add'| ||Capacity || (mgd) 統 ន Z 151,510 242,279 131,670 17,735 419,738 597,215 51,427 485, 233 \$67.720 2,4% 72,064 58,891 \$42,550 137.238 87,856 1,962,900 Sant 1 STORN 3 Rdditional Capacity (mgd) 79,550 55 器 ¥ 3 ă 84° CONVEYANCE II Store A II Add'l IICapacity II (mgd) 8 Capacity (inch-feet) 140,110 52,255 165, 477 43,314 103, 129 40,872 15,604 36,179 14,078 4,402 25,477 \$18.094 \$9.217 \$6.124 \$33.436 8 8 Part Post STORM 2 Additional Capacity (agd) 11,450 8 Page Sf. 080 Peak CSO 11 Add'1 Capacity 1[Capacity (mgd) 11 (mgd) Cost of Addit. Cap. Pipelines # 144.5/inch-foot (\$1988 millions)
Cost of Addit. Cap. for E. B. Outfall # 155.7/inch-foot (\$1988 millions) Reach Base Flow Capacity || Storm || Length w/ Alki of Reach || Icapacity (feet) (mgd) (mgd) || 11 (mgd) 효 == = INITIAL ន **12 12 12** ¥. 82 112 2 R TOTAL COST OF ADDITIONAL CAPACITY, \$1988 millions 82,88 3,88 9,000 9,000 1,60 2,538 82. • 5,500 1,465 Norfolk TOTAL in-ft of Addt Pipeline Capi East Marginal Pump Station Large Interbay Plant Additional CSO Treatment West Point Effluent P.S. borth Trunk Pump Station DUWALISH PUMP Station Interbay Pump Station **JUMARISH Pump Station** Elliot Bay Outfall Interbay STP Interbay STP lest Seattle Connet icut **Xichigan** lanford Brandon ander

(1) Additional pipe diameter capacity based on assumed flow velocity of 5 fps. (2)Flows in excess of 365 mgd exit through Elliott Bay Outfall.

STORM 3 STORM 5 STORM 5 STORM 5 STORM 5 STORM 5 STORM 5 STORM 6 STORM \$126.977 \$17.179 139, 119 1,588,624 3,680,485 8 0 ž 275 E ş 8 3 2 23 II Add'1 IICapacity II (mgd) 35 1,408,968 \$112,474 \$15,234 144,015 416,402 95,738 245,093 78,801 295, 138 124,321 132,935 3, 260, 113 273, 506 \$63.576 • M 2 33 Ŷ II Add'1 IICapacity II (mgd) d 183,384 341,748 74,440 57,662 208,802 69,607 60,540 176,971 \$78.474 \$9.858 \$37.8% CII G 11,844 2,274,597 \$136.227 3 ĸ 3 DISKS:/CSOCON/INCONANS.WK1 ||Capacity ||Capacity || (mgd) \$38.184 11 134,686 314,604 70,610 H 1125.583 11 181,384 213,231 86,938 916,552 2,246,065 72,064 177,919 \$77.489 \$9.910 139,537 58,891 80,872 2,4% X 프 졄 23 ស៊ II Add'1 IICapacity III (mgd) 8 æ 27,580 I. \$39.74! III 38,2% - 2% 180'2 60,675 67,723 75,483 14,078 86,239 161,679 Şţ. 894,660 \$30.866 \$3.380 \$5.496 ¥, 8 8 8 8 Peak CSO 11 Add'1 Capacity IICapacity (mgd) 11 (mgd) Cost of Addit, Cap. Pipelines # 33, 5/inch-foot (\$1988 millions)
Cost of Addit, Cap. for E. B. Outfall # \$55, 7/inch-foot (\$1988 millions) 뎚 ੜ TOTAL COST OF ADDITIONAL CAPACITY, \$1988 millions 7,170 1,500 17,000 5,500 11,600 2,530 1,465 4,550 3,65 8, 18 Norfolk TOTAL in-ft of Addt Pipeline Capi East Marginal Pump Station North Trunk Pump Station Large Duwamish Plant Additional CSO Treatment **Numerish Pump Station** Jumamish Pump Station Interbay Pump Station Juwamish Landfill Dumamish Outfall JUNEAN STP dest Seattle Connet icut Michigan tanford Brandon Denny

490, 107

115,141 287,897

153,057

139, 537

335,592 140,190

90,20g

146,843

53,969

0

308,419

\$82.104

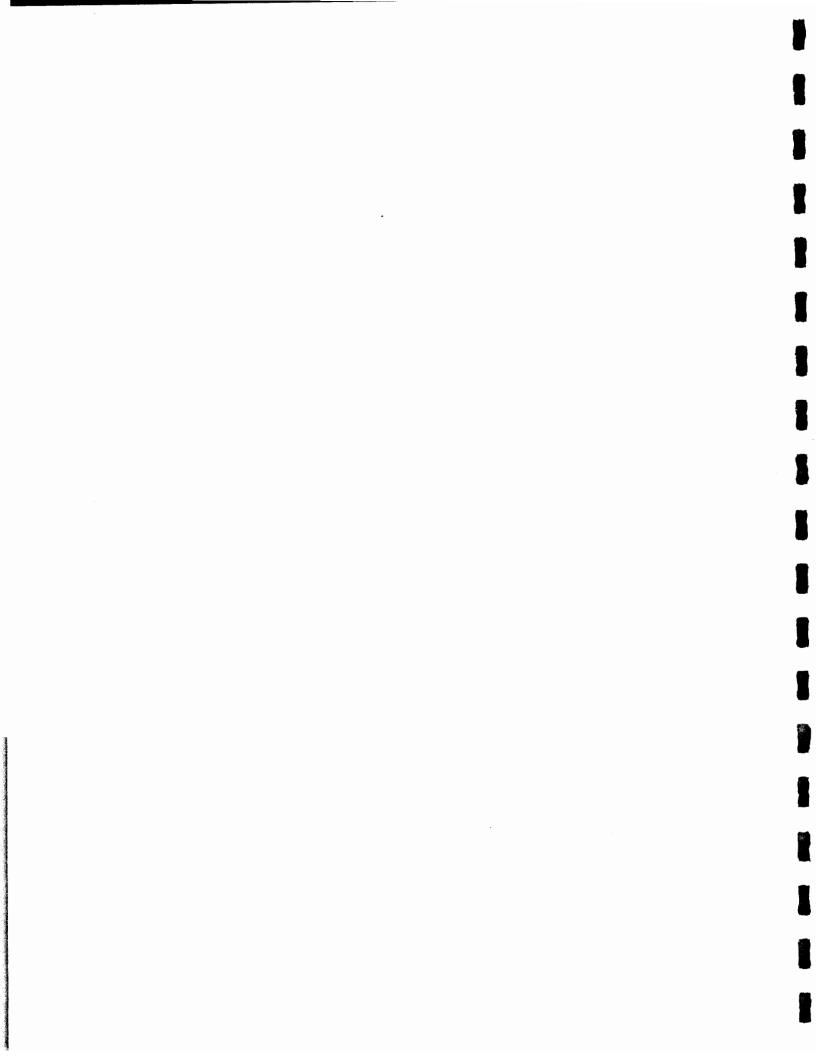
£28.260

(1) Additional pipe diameter capacity based on assumed flow velocity of 5 fps.

B-2

STORM 4 STORM 2 STORM 2 STORM 3 STORM 4 STORM 4 STORM 5 STORM 171,339 146,843 54,788 83, 106 336,338 \$105.763 \$28.985 87,856 214,228 139,843 \$32.436 \$75.696 13 ž 8 5 II Add*1 IICapacity II (mgd) 355,646 76,446 307,609 127,068 &Z¹¥ 134,846 132,935 2,935,138 155,535 155, 101.262 \$24.235 87,856 1,440,106 í¹) 8 378 Û || Add'| ||Capacity || (mgd) M Û 110,575 49,644 045,03 109'69 \$18.535 \$31.666 97,287 199,509 150.991 日本日 Cost 1 27,600 2 꽖 84 ANALYSIS 79,231 63,033 2, 4% 58,891 1, 731, 237 174, 308 76, 563 929,78 223, 456 897,952 72,064 \$59.728 \$13.974 91,406 26,572 138,280 34,000 24,000 SKW:/JGOCON/INCONDNG.WK1 II sdd'l IICapacity II (mgd) 3 K 16,018 12,451 \$14.054 \$2,466 52,707 20, 123 14,078 \$ £.223 123. B44 59,532 228,057 Plant I 00° • Peak CSO 11 Add11 Capacity ||Capacity (agd) || (agd) t (\$1988 millions) inch-foot (\$1988 millions) = K K 0 3 £8 Ş ĸ TOTAL COST OF ADDITIONAL CAPACITY, \$1988 willions of Addit. Cap. Pipelines # \$34.5/inch-foot of Addit. Cap. for E. B. Outfall # \$55.7/ii 83,000 23 3,000 3,650 s, 18 8 10,500 Norfolk 1019L in-ft of Addt Pipeline Capli Duwamish Outfall Elliot Bay Outfall (2) CSO Treatment, Interbay CSO Treatment, Duwamish End of West Point Dutfall (2) Lest Point Effluent P.S. (2) REACH ENDPOSINT (KING SPLIT) East Marginal Pump Station Saall Int./ Saall Duw. Add'l CSO Treatment, Inte Add'l CSO Treatment, Inte Worth Trunk Pump Station **BUNAMISH PUMP Station** Interbay Pump Station JUMBARISH Pump Station Junamish Landfill Interbay STP Interbay STP lest Seattle JUNEBISH STP onnet icut **Hichigan** Hanford randon ۵

1) Additional pipe diameter capacity based on assumed flow velocity of 3 fps. 2) Flows in excess of 325 mgd downstream of interbay plant exit through Elliott Bay outfall.



APPENDIX C

PROJECT SCHEDULING USED TO DEVELOP PRESENT-WORTH COSTS FOR PHASED CONSTRUCTION AND SUMMARY OF RESULTS

.

CSO CONTROL SECONDARY ALTERNATIVES 1 AND 2 75 PERCENT CSO VOLUME REDUCTION

	Year	Year
<u>Project</u>	<u>Initiated</u>	On-Line
Hanford Separation	1986	1990
CATAD Modifications	1986	1990
Green Lake/I-5 Separation	1986	1992
Added Secondary Plant O&M		1994
Alki CSO Plant	1988	1994
Parallel Fort Lawton Tunnel	1992	1998
Carkeek CSO Plant	1990	1994
Michigan Separation (10%)	1992	1996
Kingdome Separation	1995	2001
Diagonal Separation	1998	2002
NSA Separation Projects	1998	2006

CSO CONTROL SECONDARY ALTERNATIVES 1 AND 2 90 PERCENT CSO VOLUME REDUCTION

	Year	Year	
<u>Project</u>	<u>Initiated</u>	On-Line	
CATAD Modifications	1986	1990	
Hanford Separation	1986	1990	
Green Lake/I-5 Separation	1986	1992	
Added Secondary Plant O&M		1994	
Alki CSO Plant	1988	1994	
Parallel Fort Lawton Tunnel	1993	1999	
Carkeek CSO Plant	1990	1994	
Denny CSO Plant	1996	2002	
Diagonal Separation	1995	1999	
Michigan Separation (10%)	2000	2006	
Kingdome Separation	1994	2000	
NSA Separation Projects	1988	1996	
NSA Separation (added)	2000	2006	
Michigan Separation (to 67%)	2000	2006	
University Storage	1991	1997	
			_

CSO CONTROL SECONDARY ALTERNATIVES 1 AND 2 KNEE-OF-CURVE PROJECTS

Project .	Year <u>Initiated</u>	Year <u>On-Line</u>
CATAD Modifications	1986	1990
Hanford Separation	1986	1990
Green Lake/I-5 Separation	1986	1992
Added Secondary Plant O&M		1994
Kingdome Separation	1992	1998
Diagonal Separation	1998	2002

CSO CONTROL SECONDARY ALTERNATIVES 3 AND 4 75 PERCENT CSO VOLUME REDUCTION

	Year	Year
Project	<u>Initiated</u>	On-Line
Hanford Separation	1986	1990
CATAD Modifications	1986	1990
Green Lake/I-5 Separation	1986	1992
Parallel Fort Lawton Tunnel	1991	1997
Alki CSO Equalization	1988	1994
Carkeek CSO Plant	1990	1994
Denny CSO Plant	1995	2001
Kingdome Separation	1992	1998
Diagonal Separation	1994	1998
NSA Separation Projects	1997	2005
Michigan Separation (90%)	1998	2004

CSO CONTROL **SECONDARY ALTERNATIVES 3 AND 4** 90 PERCENT CSO VOLUME REDUCTION

	Year	Year
Project	<u>Initiated</u>	On-Line
Hanford Separation	1986	1990
CATAD Modifications	1986	1990
Green Lake/I-5 Separation	1986	1992
Parallel Fort Lawton Tunnel	1988	1994
Alki CSO Equalization	1988	1994
Carkeek CSO Plant	1990	1994
Denny CSO Plant	1994	2000
University Storage	1991	1997
Diagonal Separation	1995	1999
NSA Separation Projects	1988	1996
Michigan Separation	2000	2006
Duwamish CSO Plant (100 mgd)	1997	2003
Kingdome Separation	2000	2006
NSA Separation (added)	2000	2006

CSO CONTROL SECONDARY ALTERNATIVE 4 **KNEE-OF-CURVE PROJECTS**

Project	Year <u>Initiated</u>	Year <u>On-Line</u>	
CATAD Modifications	1986	1990	
Hanford Reduction	1986	1990	. 3
Green Lake/I-5 Separation	1986	1992	* .
Kingdome Separation	1992	1998	
Diagonal Separation	1996	2000	
Michigan Separation (90%) AUX (50 EQUALIZATION	2000 1988	2006 1984	CAC
Conteck CGO PLANT	1990	1999	Jet 95
	_		

Acki Equilization 18.5 1988

19.2 PN

Carleek

1.8 10 1988

4.3 10 PN

Denny Way

C-3 V9-8 Congress

52.2 PN

CSO CONTROL SECONDARY ALTERNATIVE 5D: LARGE DUWAMISH 75 PERCENT CSO VOLUME REDUCTION

<u>Project</u>	Year <u>Initiated</u>	Year <u>On-Line</u>
Hanford Separation	1986	1990
CATAD Modifications	1986	1990
	1986	1992
Conveyance Improvements	1988	1994
Alki and Carkeek CSO Plants	1988	1994
Added Secondary Plant O&M		1994
Fort Lawton Storage	1993	 1997
EBI Storage	1989	1995
→ Diagonal Separation	· 1995	1999
NSA Separation Projects	- 1995	2003
* Kingdome Separation	- 2000 Fann Kalesair &	75% & 66% reduction

CSO CONTROL SECONDARY ALTERNATIVE 5D: LARGE DUWAMISH 90 PERCENT CSO VOLUME REDUCTION

	Year	Year
Project	<u>Initiated</u>	On-Line
CATAD Modifications	1986	1990
Hanford Separation	1986	1990
Green Lake/I-5 Separation	1986	1992
Fort Lawton Storage	1992	1996
Added Secondary Plant O&M		1994
Conveyance Improvements	1988	1994
Alki and Carkeek CSO Plants	1988	1994
EBI Storage	1989	1995
NSA Separation Projects	1991	1999
Diagonal Separation	1996	2000
Kingdome Separation	1997	2001
University Storage	1997	2003
Kingdome Separation (balance)	1997	2001
Michigan Separation	2000	2006
NSA Separation (added)	2002	2006

CSO CONTROL SECONDARY ALTERNATIVE 5D: LARGE DUWAMISH KNEE-OF-CURVE PROJECTS

	Year	Year
<u>Project</u>	<u>Initiated</u>	On-Line
Alka & Cackeed CSO 1988-1994. Hanford Separation		
Hanford Separation	1986	1990
CATAD Modifications	1986	1990
Green Lake/I-5 Separation	1986	1992
Conveyance Improvements	1988	1994
Added Secondary Plant O&M		1994
EBI Storage	1994	2000
Diagonal Separation	2000	2004

CSO CONTROL SECONDARY ALTERNATIVE 5I: LARGE INTERBAY 75 PERCENT VOLUME REDUCTION

Project	Year Initiated	Year <u>On-Line</u>
Hanford Separation	1986	1990
CATAD Modifications	1986	1990
Green Lake/I-5 Separation	1986	1992
Alki and Carkeek CSO Plants	1988	1994
Conveyance Improvements	1988	1994
NSA Separation Projects	1991	1997
Diagonal Separation	1995	1999
Kingdome Separation	1996	2002
Michigan Separation	1997	2003
University Storage	2000	2006

CSO CONTROL SECONDARY ALTERNATIVE 5I: LARGE INTERBAY 90 PERCENT CSO VOLUME REDUCTION

	Year	Year	
<u>Project</u>	<u>Initiated</u>	On-Line	
CATAD Modifications	1986	1990	
Hanford Separation	1986	1990	
Green Lake/I-5 Separation	1986	1992	
Alki and Carkeek CSO Plants	1988	1994	
Conveyance Improvements	1988	1994	
Denny CSO Plant	1995	2001	
Diagonal Separation	1995	1999	
NSA Separation Projects	1991	1997	
Kingdome Separation	1998	2004	
Michigan Separation	1997	2003	
University Storage	1992	1998	
Michigan Separation (balance)	1997	2003	
NSA Separation Projects (balance)	2000	2006	

CSO CONTROL SECONDARY ALTERNATIVE 5S: SPLIT INTERBAY/DUWAMISH 75 PERCENT CSO VOLUME REDUCTION

<u>Project</u>	Year <u>Initiated</u>	Year <u>On-Line</u>
Hanford Separation	1986	1990
CATAD Modifications	1986	1990
Green Lake/I-5 Separation	1986	1992
Added Secondary Plant O&M		1994
Added Conveyance from King Street	1988	1994
Conveyance Improvements	1988	1994
Alki and Carkeek CSO Plants	1988	1994
EBI Storage	1991	1995
Diagonal Separation	1993	1997
NSA Separation Projects	1990	1998
University Storage	1995	2001
Kingdome Separation	199 5	2001
Michigan Separation	1998	2006

CSO CONTROL SECONDARY ALTERNATIVE 5S: SPLIT INTERBAY/DUWAMISH 90 PERCENT CSO VOLUME REDUCTION

	Year	Year
<u>Project</u>	<u>Initiated</u>	On-Line
CATAD Modifications	1986	1990
Hanford Separation	1986	1990
Green Lake/I-5 Separation	1986	1992
Added Secondary Plant O&M		1994
Alki and Carkeek CSO Plants	1988	1994
Conveyance Improvements	1988	1994
Added Conveyance from King Street	1988	1994
EBI Storage	1991	1995
Denny CSO Plant	1997	2003
NSA Separation Projects	1990	1998
NSA Separation (added)	1994	2000
Diagonal Separation	1996	2000
University Storage	1991	1997
Kingdome Separation	2000	2006
Michigan Separation (balance)	2000	2006
NSA Separation (balance)	2002	2006
Michigan Separation	2002	2006

SUMMARY

PRESENT WORTH OF CSO CONTROL COSTS
USING PHASED PROJECT CONSTRUCTION

Secondary	Percent	Discount	· Propos	nt Worth C	11000 M:11:	_	
Alternative	Reduction	Rate	<u>Capital</u>	O&M	1988 Millio Eq. Rep.	<u>n</u> Total	
71110711111710	11000011011	TOTAL	Capital	<u>SQ1VI</u>	Eq. KQD.	Total	
1 & 2	75	10.0	92.89	9.81	1.07	103.77	
•	75	8.5	89.13	10.70	1.19	101.02	
•	90	10.0	174.96	10.95	1.81	187.72	
· •	90	8.5	167.60	11.96	2.02	181.58	
3 & 4	75	10.0	152.92	3.32	1.00	157.24	
•	75	8.5	146.29	3.64	1.11	151.04	
	90	10.0	249.63	4.90	1.72	256.25	,
•	90	8.5	238.40	5.41	1.93	245.74	
51	75	10.0	120.62	7.34	0.48	128.44	
•	75	8.5	116.35	8.00	0.53	124.88	
*	90	10.0	189.90	8.38	1.37	199.65	
*	90	8.5	181.90	9.15	1.52	192.57	
5D	75	10.0	115.73	11.03	0.47	127.23	
	75	8.5	112.19	12.03	0.52	124.74	
•	90	10.0	165.28	11.27	0.48	177.03	
#	90	8.5	159.09	12.30	0.53	171.92	
5S	75	10.0	125.28	11.19	0.49	136.96	
*	75	8.5	121.19	12.21	0.54	133.94	
#	90	10.0	193.31	11.86	1.04	206.21	
*	90	8.5	185.23	12.95	1.16	199.34	W/Alki & Carkeck
2	KOC*	10.0	35.64	3.54	-0-	39.18	61
•	•	8.5	34.84	3.85	-0-	38.38	
4	KOC*	10.0	50.55	0.04	-0-	50.59	75
• .	•	8.5	48.62	0.04	-0-	48.66	
5D	KOC*	10.0	64.40	4.04	-0-	68.44	90
•	*	8.5	63.11	4.46	-0-	67.57)

^{*} Knee of the Cost/Benefit Curve

